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BY-PRODUCTS IN GAS MANUFACTURE.[1]

BY

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IN dealing with the interesting topic which has been assigned me in this Centennial Celebration it seems proper, and in the interest of clearness of treatment, to deal broadly with the subject of by-products before dealing with those of the Gas Industry. I have, but a short time ago, been called on to prepare an article on this subject for the Loose Leaf Encyclopædia, and with your permission I will quote part of this article, since I feel that I have therein presented the matter to the best of my ability.

"By-products are substances or results obtained in the operation of a specific process, in addition to the substance or result

[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of The American Philosophical Society, The Franklin Institute, The American Chemical Society, and The American Gas Institute, in the hall of the Franklin Institute, Philadelphia, on Thursday, April 18, 1912.

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primarily sought. In hunting game for food, the hides and feathers are by-products; in hunting game for hides or pelts, the carcasses are by-products; in manufacturing lumber, the sawdust and shavings are by-products; in brewing beer, the yeast is a by-product.

"In the classification of the products of manufacture, three groups are recognized—viz., *principal product*, which is that product of an establishment manufacturing more than a single product that has the largest total value; *subsidiary product*, which is a product of such an establishment having a less total value; and *by-product*. A subsidiary product may be a utilized by-product, or it may be the product of an allied industry—as, for instance, bookbinding in a printing office, or compounding fertilizers in a cottonseed-oil mill. This last example is one of many occurring in factories where the by-product of the principal industry—in this case cottonseed meal—becomes the raw material for the manufacture of a subsidiary product. The development and growth of manufactories using manufactured products as the raw material for further manufacture has not infrequently created such a change in the demand for the products of the primary establishment as to make one of its subsidiary products its primary product. A notable example of this is the Le Blanc process for the manufacture of soda products from common salt by the action upon it, in the first stage of manufacture, of sulphuric acid. In this operation, hydrochloric acid gas is given off as a by-product. At first this was wasted by being allowed to escape into the atmosphere, where it produced most devastating effects. To avoid the nuisance thus created, this gas was collected by dissolving it in water, and sold, thus becoming a subsidiary product; but with a greatly increased demand for this substance, for the manufacture of bleaching powder and other uses, through which its value was enhanced, and with the competition of electrolytic and other processes, through which the cost of the production of sodas was reduced, hydrochloric acid became in many cases the principal product of the Le Blanc factories.

"As indicated by the examples cited, the custom of utilizing by-products is a very ancient one in its origin, though frequently in the newer countries, where the raw material was abundant, or in the early development of industries, where the unit of pro-

duction was small and competition slight, the by-products have generally been wasted, and frequently have become sources of nuisances. But with the increase in density of the population, through which the necessity for abating the nuisances became urgent; with the increase in the unit of production; with a diminution in the quantity of the raw material, or the ease with which it could be obtained; and with the increase in competition, additional attention has been given to the utilization of the by-products of manufacture, until to-day they have become of great importance in all industries, and of such commercial value that the creation and maintenance of many establishments have been determined by the ability to utilize and dispose of the by-products of their processes.

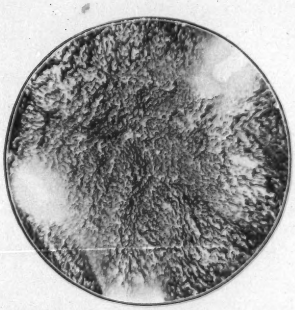
"Naturally, the by-products that were first to be utilized were those which were most readily observed and whose uses were most obvious. The by-products which ran off in solution or passed away as gases, or forms of energy, such as heat, or those whose uses were remote or less readily apparent, have until very recent times been allowed to go to waste. The discovery of the first of the aniline coloring matters, mauve, in 1856, by the English chemist William Henry Perkin, and the fact that the aniline from which it is manufactured could be obtained in abundance from coal tar, gave an impetus to the utilization of the last enumerated by-product; and the rapid growth in commercial importance of the coal-tar products industry so concentrated attention on this phase of manufacture that the utilization of by-products has gone on with increasing expansion ever since."

There exists a rather widely extended popular belief that the "coal-tar colors"; many perfumes, flavors and synthetic drugs; and numerous other substances, are by-products of the gas industry, but such is not the case, for they are produced by the further manufacture of the by-products of this industry. This view limits the scope of my topic, which is, however, broadened by the modern view of the gas industry in that it embraces in its consideration not only coal gas, but all gases manufactured for the generation of light, heat or power and which are distributed for use by public service organizations. All of the processes of manufacture employed in the production of these gases depend upon the chemical transformation of the materials

used, and in all processes other products beside the gas sought are yielded.

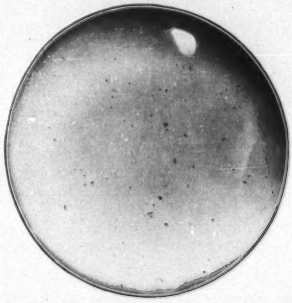
This is particularly true in the carbonization or, using the more precise chemical term, the thermolysis, of peat, wood, resin, coal, oils, and other organic bodies, in which these bodies are subjected to widely ranging degrees of temperature and quantities of heat when enclosed in containers, such as retorts, ovens, or kilns, which more or less completely prevent access of air to these bodies during the thermolyzation process, and which are so operated that the heat, which effects the thermolysis, is conveyed to them through the walls of the containing vessel. For these bodies are complexes. The simplest of them, such as the

FIG. 1.



Coal gas tar.

FIG. 2.



Water gas tar.

resins, produced from exudates from deciduous vegetation or the thermolyzation of such exudates, and the distillates of petroleum, are still complexes. They are not elementary. They are not even single chemical compounds, but they are aggregates of chemical compounds each of which is capable, under certain conditions of temperature and pressure, of undergoing a particular kind of decomposition with the production of certain particular products, each of which, were they to remain apart, might be of such character as to form a useful product, but, being mixed, or associated with other products the tendency is that these intermediate products of thermolysis react with one another and that the final product, which may be, and usually is, a mixed

product, is a final integration of the process as it has proceeded from its initial condition, through its manifold transformations, to its end condition.

The conditions described are those which especially obtain for coal, as known in England, or bituminous coal as it is styled in the United States. This is the substance which first met with general success and which is yet to-day largely used in the manufacture of gas. It is the substance from which coal gas, so styled, has been and still is produced and though commercially regarded as, and popularly believed to be a definite and individual substance it is not so, for it not only varies in its composition, constitution and characteristics as it is obtained from different localities, but it varies by degrees as it is obtained from different geological deposits in the same geographical locality and may even vary in the deposits of the same geologic age, or, in technical parlance, of the same seam, according to the conditions to which it has been subjected. The vicissitudes to which coal forming materials are subjected in this conversion from cryptogamous vegetation, such as prevails in peat, or phenogamous vegetation in its many species, through lignite into coal, is admirably portrayed by Dr. T. E. Thorpe [2] and the manifest complexity and variability of the product is there well indicated. The geological significance of these transformations of vegetation are set forth by J. D. Dana in that charming, yet accurate style, of which he was a master.

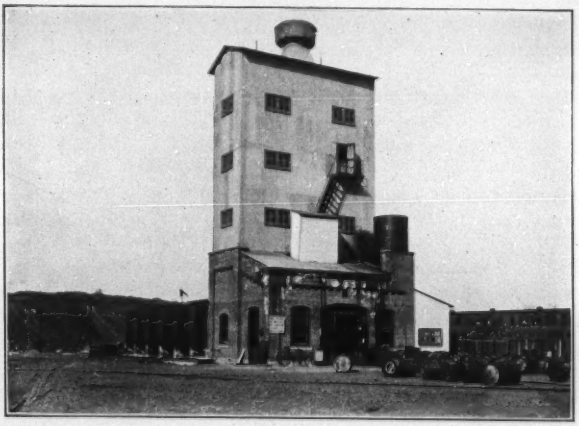
Notwithstanding this recognition of complexity we have known nothing definitely as to the constitution of coal or of the nature or amount of its components. A large number of ultimate analyses, showing the percentages of carbon, hydrogen, oxygen and nitrogen present in ash-free coal, have been made and recorded in literature, as have also many proximate analyses giving the percentages of moisture volatiles, coke, or fixed carbon, and ash, with the sulphur and phosphorus contents. Such data has had and still has an economic value in gas making and coke making and in the utilization of the coal, or some of its products, in iron smelting or steel working, but it still leaves us uninformed as to what there is in the different varieties of coal or in any given coal. And we are not much further enlightened

[2] "Coal: Its History and Uses." Macmillan & Co., London, 1878.

by the interesting comparison made by Pennock,[3] and others, of the character and composition of the tars yielded by different coals whose proximate compositions had been precisely determined, for these tars were the products of thermolysis, accompanied no doubt by metathetical changes also.

It has long been known that peat, lignite and bituminous coal, certainly, are affected by some solvents. In the early days of my professional career I devised a scheme for the classification of coal producing substances, and the different varieties of

FIG. 3.



Benzol plant.

coal, based on the character of the colors which they imparted to aqueous potassium hydroxide solutions in which the powdered material had been digested. There is some question in this case as to whether the extracted matter was identical with that in the coal or whether it had chemically reacted with the strongly alkaline reagent used. It is known, however, that we have many neutral liquids such as alcohol, benzene, ether, chloroform, acetone, carbon tetrachloride, carbon disulphide, pyridine, ligroin and other petroleum distillates, to mention but a few at com-

[3] J. D. Pennock, *J. Am. Chem. Soc.*, 21, 696, 1899.

mand, which are solvents of organic substances, through which hydrocarbons and their derivatives which may be present in the coal can be extracted unchanged, while by the action of reagents of known behavior, such as nitric acid, chlorine, caustic alkalies in the molten condition and the like, derivatives of these organic substances, whose genetic relationships are known, may be obtained, and thereby, through both direct and indirect methods of approach, the constitution be ascertained.

Records of the attempts made to solve this problem of the constitution of coal, by means such as described with the results thus far obtained, have been assembled and critically reviewed in a masterly manner by Frank Wiggleworth Clarke in his "Data of Geochemistry,"[4] and it can only be said that the results are most meager, largely because the extractives are usually tars which require further treatment for separation and identification, by slow and tedious processes and that the total yields are rarely large. It may be of interest to announce that the recently created U. S. Bureau of Mines has taken up this problem as one of its studies looking to a more complete and economic utilization of our coal and therefore to the conservation of our fuel resources, and that the results of the preliminary investigations on these lines by J. C. W. Frazer and E. J. Hoffman, of that Bureau, have been prepared for publication. I feel assured that as more definite information is acquired the character of our distillation processes, such as are now used in gas and coke making, will be profoundly modified and that the nature and yields of the by-products of the gas industry will be materially changed.

Taking the industry as it has been and now is, it may be noted that the by-products of the coal gas industry are coke, gas, carbon, tar, ammoniacal liquor and spent purifying material, either lime or oxide. In the water gas industry tar and purifying material, with a meager amount of ammoniacal liquor. In the oil gas industry lampblack, tar and spent purifying material for the new Lowe process, and "hydrocarbons" for the cracked and compressed oil gases. While in the acetylene gas industry calcium hydroxide is practically the only product incidental to the reaction other than the acetylene.

[4] Bulletin 491 (2d ed.) U. S. Geological Survey, pp. 705–731, 1911.

From the outset the commercial and economic value of certain of the collateral products obtained from the chemical reactions which yield coal gas were recognized, and to such an extent that the original organization, whose parliamentary recognition we now celebrate as a significant event in the evolution of chemical industries, was styled the "Chartered Gaslight and Coke Company"; the production of coke, by the distillation process employed apparently being regarded by Winsor and his associates, as of equal, or nearly equal industrial importance to that of coal gas. We know that in the last quarter century the rela-

FIG 4.

Blow case.

tive economic importance of the gas and coke obtained from bituminous coal by distillation processes has been, and to-day still is, in many localities or under certain industrial conditions, reversed, and that where by-product coke ovens are employed the coke is the principal product and coal gas is one of the subsidiary by-products. In by-product coke making, particularly where gas is supplied to public service corporations, for distribution, as is often the case, the other by-products are substantially those of the coal gas industry.

I say "substantially" with intent for they would be identical

only by the most remote chance since it is recognized that, using the same coal, the products obtained differ in quantity and character when thermolyzed in the same retort with variations in the rate, degree and method of heating them, and with the pressures put upon, and that when the device employed, such as vertical or inclined retorts, or ovens of the many dimensions and forms known, is substituted for the horizontal retort of standard type, the conditions under which the thermolyses and metatheses take place are so varied that the products are materially varied both in composition and quantity, and this difference is emphasized

Fig. 5.

Refined storage tanks.

when the material treated differs, as does coal from different localities or even from the same locality but from different parts of the vein.

My presentation of the difficulties which beset the gas manufacturer in his endeavor to produce a gas of uniform character that will conform to the regulations or restrictions placed on him by the state or municipal legislation or ordinance with which he is environed may perhaps have quickened your interest or stimulated your incredulity. If so this part of my thesis is completed.

But I call attention to the fact that complex and variable as the gaseous products of soft coal distillation are, the tar and ammoniacal liquor which are by-products are subject to as marked variations in yields or in composition or both with differences in the coal used and the processes or devices employed and in their operation as the gas is and that these, but more particularly the tar, are the by-products which have lent special interest to the gas industry and which in the more recent years have proved to be important factors in its commercial success and in enabling this industry to maintain its place commercially in the presence of competing illuminants.

Of these by-products the ammoniacal liquor is chemically the simplest and yet it is complex and variable. It is produced from some of the nitrogen in the coal, and perhaps to a degree, when alkalies or alkaline earths are present from atmospheric nitrogen entering, or included in the chamber in which the destructive distillation of the coal is effected. Varying with the process employed and its operation the ammonia content appears in the condensates as carbonate, sulphide or polysulphide, chloride, cyanide, sulphocyanide, and probably in other combinations, from which it is released, to a greater or less extent, by the action of stronger hydroxides, such as calcium hydroxide, in the process of recovery when it is converted into the marketable forms of ammonia water or ammonium sulphate.

In this latter state of combination the nitrogen of the coal or the atmospheric nitrogen which has entered into this state of combination, has become available for food for vegetation, whereas before it was not so. This forcibly illustrates the correlation of country and city, of agriculture and manufacture, for while the coal remained unmined its nitrogen content was unavailable as plant food, but when that coal had been mined and employed in the manufacture of gas for city or town lighting its nitrogen content was not only released from its inert condition of combination but brought into such association, through subsequent treatment, as to be available for plant food. To-day a larger part of the available nitrogen necessary for use in compounded fertilizers or for direct use in agriculture comes from the gas industry, or from its closely correlated industry, the by-product coke industry.

The utilization of ammonium sulphate from the gas indus-

try in agriculture practically dates from the time of the governmental encouragement of the beet-root sugar industry in Germany. It is in this way correlated with the potash industry which has been so recently a serious topic for diplomatic negotiations and which to-day remains a grave problem for governmental solution. Personally I find the available nitrogen question to be a wider one than that of agriculture. I find it to be closely concerned with the ability of a nation to protect and defend itself in a prolonged warfare. I find that in the immediate past and to-day the supposed dominant nations have been and are, through the necessity for available nitrogen in warfare, dependent nations since they have sought for this available nitrogen the few sources of supply where it has been stored by nature's agencies working in a comparatively simple manner. I have elsewhere suggested [5] that chemistry has in recent years released these nations from their state of dependency. It seems at first thought a far cry from the manufacture of gas, by which to extend the efficiency and efforts of the people of a nation, to its defense in time of attack, but chemistry has made this last relation relatively close and the gas industry, if properly directed, may reasonably be expected to become a factor in the defense of the nation and its managers may rightly feel that in wisely and justly directing the affairs of a gas company they are not only rendering a public service but a patriotic service also.

In the development of the ammonia recovery from coal gas a rather amusing and curious condition has developed. Originating as the gas industry did in England that country has maintained its supremacy in the production of by-products and when ammonia and ammoniacal compounds from this source began to assume economic importance there was devised in England a means for ascertaining the quantity of the valued component in a liquor by liberating it from its state of combination, through the aid of calcium hydroxide, and then measuring its neutralization with a standard solution of sulphuric acid which had been made up on the scale of Winchester gallons. This method of determining the ammonia content of liquors, known as "ounce-strength," was on its face obviously fair and equitable and was

[5] "The Nitrogen Question from the Military Standpoint," U. S. Naval Inst., Proc. 35, 715, 1908. Smithsonian Report for 1909, 225–236.

shortly afterwards introduced into this country, but the difference in measures was overlooked and the standard sulphuric acid was made up with the U. S. gallon as the measure and ever since "ounce-strength" has had in the United States a different significance from that which it has had in England. Fortunately the content in real NH_3 or $(NH_4)_2SO_4$ is coming more commonly into use and the discrepancy of statistics which has existed between different countries is being reconciled.

The vagaries of nitrogen in forming its various associations

FIG. 6.

Loading tanks.

by which the many compounds of nitrogen found in the distillates from coal, from ammonia, and its multitude of substituted amines, to cyanogen with its numerous derivatives, result, is but one example of the multitude of complex changes and rearrangements of atoms and radical groups which occur during the process of gas making where the apparently simple method of heating the coal is employed. For numerous as the nitrogen compounds formed may be the known carbon compounds are many fold greater since they include, not only the many representatives of various known homologous groups of acyclic and

of cyclic hydrocarbons, but also many of the oxy, sulpho and nitrogen derivatives of these hydrocarbons.

Attention has been called to the necessary variations in the composition and character of the gas which must result from the variations occurring in the composition and constitution of the coal used; the differences in the forms, proportions and character of the devices used in the carbonization of this coal; and particularly in the methods employed in the carrying out of the process, but the effects of these many differences are, if possible, more obvious in the tar, which is one result, than in the gas, which is another result of the destructive distillation, and this fact is of prime importance for consideration by the gas works manager since tar stoppages are not infrequent sources of trouble in operation which may to an extent be remedied by so conducting the distillation process, in any system, as to obtain more liquid or less highly carbonized tars.

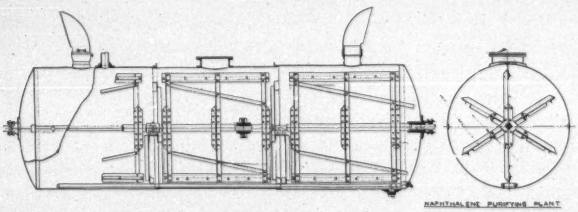
For it is well known and has long been known that in this distillation process heavy hydrocarbons or hydrocarbon derivatives of high boiling points, which have been evolved from the coal by heat, may condense before reaching the hydraulic main and fall back upon the incandescent coal mass in the retort or upon the incandescent walls of the retort or other container, where they are cracked, depositing carbon, which appears on the walls as gas carbon, and yielding lighter and more volatile gaseous products which again pass on to mix with the other gaseous products, but bearing with them some portion of the carbon, which has not been deposited, to foul the tar.

At the time that these splitting up processes are going on, or nearly simultaneously with them, building up processes may be taking place, for it is well known that under conditions such as obtain in gas retorts or in the gas making system in practical use, acetylene and acetylene homologues, such as methyl-acetylene, polymerize to benzene, and benzene homologues, such as mesitylene, which may again be decomposed into simpler products at more elevated temperatures and which pass partly to the gas and partly, and more largely perhaps, to the tar.

It is this complex, vile looking, evil smelling, adhesive, by-product, tar, which was for long a stumbling block in the development of gas lighting. Early in the progress of the industry efforts were made to utilize it, but they proved of so little avail

that when possible much of it was run off as a waste product into neighboring water courses destroying the fish, fouling the craft floating on the water and the structures bordering it, and giving rise to nuisances of a great variety of kinds. Among the unexpected results of this procedure I may recall that when in 1882, under orders from the Secretary of the Navy, I visited the Navy Yard at Brooklyn, N. Y., to investigate the cause of the corrosion of the copper sheathing of the newly fitted U. S. S. *Juniata*[6] and of other vessels which had been fitted with suits of copper at the Brooklyn yard, I found in the Wallabout considerable deposits of coal tar which had been rejected by the adjacent gas works in earlier days, and my experiments tended to show that this tar had played an important part in the corrosion which entailed considerable loss.

FIG. 8.



Naphthalene mixer.

But this coal tar which was despised and rejected by man; which was a burden to the manufacturer and a nuisance to his neighbor, has, through the researches of the chemist, become a much valued and highly considered substance, and an aid to the gas industry, which it has helped to maintain and extend, and through which the demands for cheaper gas has partly been met. Its history is filled with romance. The first English patent ever issued relative to the destructive distillation of coal was that dated August 19, 1681, and granted to J. J. Becher and Henry Serle "for a new way of making pitch and tar out of pit coal." At the outset tar was therefore to be classed as the principal product with gas and coke as by-products of the coal tar industry, but the industrial development took other courses and the order of importance was reversed until the production of

[6] Proc. U. S. Naval Institute 12, 391, 1886.

pitch and tar proceeded on such a scale that, as stated, the gas makers were compelled to dispose of it at almost any hazard and in every possible way, and yet to-day through another change in industrial development this tar has become, perhaps, the most highly prized, or at least the most intellectually honored, of all the products resulting from the destructive distillation of coal.

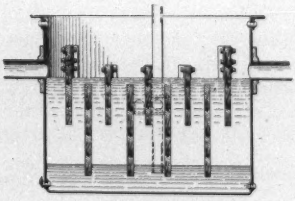
It is here that the real romance begins when studied by methods, such as those spoken of earlier in this paper as promising man information relative to the constitution of coal, and when by additional methods this blackish, viscous, forbidding appearing tar was examined it was found to be a storehouse of most interesting materials; and it has been found to be a storehouse of most fascinating possibilities and realizations.

It has been asserted that all foul smelling substances are composition of matter, and it is a fact that carbon disulphide which, notoriously, has long been condemned for its disgusting odor appears as a sweet, ethereal smelling compound when separated from its associates by the methods of purification devised by the chemists. Likewise it has been suggested that offensive looking bodies are composites. Whatever may be true of this theory in its general application it is certain that coal tar, which, in common with wood, water gas, petroleum, cotton-seed oil and other tars, of organic origin, is offensive in appearance and odor, is a product of the distillation of organic substances, and that all of these distillates are composites, and that when each of the chemically individual components of these compositions is separated from the composite mixture it appears in an agreeable condition to mankind as regards odor, or color, or as tried by other physical characteristics through which substances are differentiated or distinguished. For from coal tar there has been obtained the water white or colorless benzene and its equally colorless homologues which possess such pleasant odors and which give rise to compounds of such markedly pleasant odors that the series of hydrocarbons of which benzene is the initial member has been long since styled the aromatic series.

This is but the beginning of the enumeration of the hydrocarbons present in coal tar, for besides the benzene series there has been found present many of the conjugated derivatives of benzene, such as naphthalene, fluorene, phenanthrene, anthracene, and many others. Moreover there has been found present

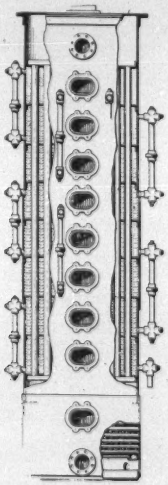
besides ammonia, nitrogen containing compounds, such as aniline, the pyridines, the picolines, the quinolines and isoquinolines and many other nitrogen containing compounds; sulphur compounds, such as thiophene and the derivative thiophenes; and hydroxy compounds, such as the phenols, and the cresols. This review embraces but a limited number of the numerous compounds which go to make up the material styled coal tar. The number and amount of each varies with the source from which the tar is obtained and the manner and means by which it is produced.

FIG. 7.



Tar separator.

FIG. 9.



Dephlegmating condenser.

No one of these separate chemical substances is to be regarded as a by-product of the gas industry, for they are usually isolated from the coal tar in other establishments than gas manufacturing establishments. They are spoken of here only that we may note the effect and influence of the gas industry on other industries, and in doing so it may be proper to recall that the substances enumerated as occurring in coal tar are not only used by themselves to produce certain useful and beneficial effects, but that they are more largely employed as the raw materials

for further manufacture, and that from them we obtain not only compositions of matter such as cleansing compounds, paints, paint removers, and the like, but also many chemical compounds having most valuable properties. It is from these isolated components of coal tar that we now produce the many coloring matters, a large part of which are used as dyestuffs, such as the aniline colors, the synthetic alizarine, which has driven the natural madder dyes from the market and which has opened the area formerly devoted to the growth of the madder root to the cultivation of food crop, and synthetic indigo which is rapidly displacing the indigo produced from natural sources. Antiseptics and germicides, such as carbolic acid and the naphthols. Explosives such as picric acid and the trinitrotoluene, known as trotyl. Flavoring materials such as the methyl salycilate and vanilline. Perfumes such as geranoil and artificial musk. Febrifuges such as antipyrine, acetanilid and many other synthetic remedies. Sweeting principles such as saccharine, and photographic developers such as hydroquinone.

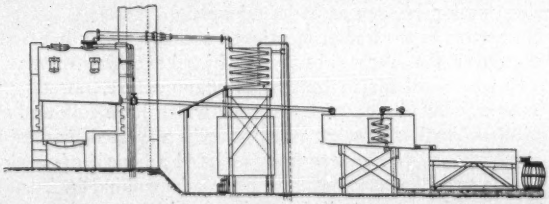
Numerous as the bodies mentioned are, they form but a very small part of the many substances which have been or may be derived from coal tar in its further manufacture, nor do they begin to exhaust the beneficent results which have followed this chemical utilization of what was formally a wasted by-product. for the coal tar dye industry has conferred a benefit of incalculable value upon bacteriology and upon all mankind by furnishing dyes which, when applied to microscopic preparations, make it possible to distinguish and recognize the germs of typhoid, cholera, tuberculosis, and other diseases; it is alleged that the industry was the principal cause of the establishment in Germany in 1877 of the imperial patent office; it is certain that the study of the constituents of coal tar and of their derivatives has created an almost new chemistry which development was largely facilitated by the ingenious speculations of August Kekulé regarding the constitution of the benzene ring advanced by him in a masterly treatise in 1865. Largely because of the insight which this theory of Kekulé gave man regarding the constitution of benzene and the possibility of obtaining from it, and its homologues, many of the chemical compounds already known and desired and many others indicated but not previously known, an enormous industry was created which within forty years from the promulgation of the theory employed more than 15,000 workmen in

Germany alone, producing products of a commercial value reaching to tens of millions of dollars and advancing the industry of mankind in a multitude of ways.

While coal gas tar has for more than a half century played a most important part in the chemical development of many countries, water gas tar which has been produced, particularly in this country, in very large quantities, has until recently been an unutilized by-product except in so far as it has been used for fuel, when mixed with breeze, under the retorts of boilers or as a source of power, in internal combustion engines, such as the Diesel engine, but through the investigations directed by Mr. W. H. Gartley, this material of which we have a most abundant supply has recently been made to yield its valuable components for use in further manufacture.

Water gas tar is a very complex mixture of a great many

FIG. 10.



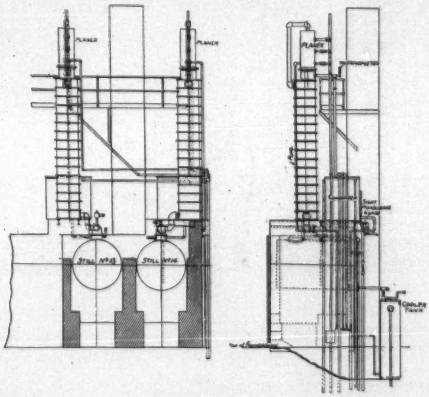
Tar still.

hydrocarbons. The principal commercial hydrocarbons are probably as follows: Benzol, toluol, xylol, naphthalene, methylanthracene, phenanthrene, and probably in the pitch, chyrsene and pycene. Water gas tar is formed in the carburetter and apparatus by the contact of the oily vapors, used in carburetting, with the highly heated checker brick. Its formation differs from that of coal tar, in that the temperature which obtains is moderate and is very exactly regulated and the time of contact is short and uniform, and furthermore, there is a high percentage of hydrogen present at the start due to the water gas which is to be carburetted. The free carbon, therefore, in water gas tar is very low compared with that in coal gas, and its composition is generally more uniform. The oil used for enriching carburetted water gas varies in character from the paraffine base oils of Pennsylvania and Ohio to the asphaltic base oils of Texas

and California. The presence of the hydrogen in water gas as affecting the formation of the tar is shown by the increased amount of olefines and the smaller amount of tar formed, which is more complex in its nature in the case of water gas tar than the tar formed by the simple decomposition of the oil.

The general differences between water gas tar and coal tar are that water gas tar has a very low free carbon content; corresponding fractions have a slightly lower gravity; a larger fixed carbon content; absence of oxygenated compounds and a general increase in methylated derivatives, especially in the higher hydrocarbons, this confirming, in general, Schulze's theory of

FIG. 11.



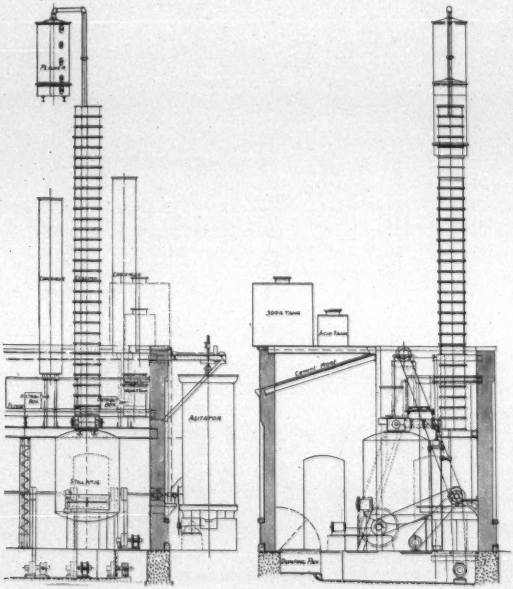
Fire column still.

pyrocondensations at lower temperatures. Water gas tar varies in character somewhat according to the original character of the oil and to the method of operation of the set, particularly as regards the temperatures carried in the fixing vessels.

The water gas tar as it leaves the apparatus exists generally in the form of vapor. This is dropped out when the temperature of the gas is reduced in the wash-box, scrubbers and condensers, and the last traces are removed in the P. & A. tar extractor. A considerable quantity of water is also condensed at the same time, and the mixture of oil and tar is separated by utilizing the differences in specific gravity. The crude tar thus

separated still contains considerable amounts of water held in suspension. This is further separated by storage of the crude tar in large tanks, where in time the water separates out to such an extent that the tar will contain not over 1 or 2 per cent. of water.

FIG. 12.



Steam stills.

The crude tar is distilled in a fire still; that is, one provided with direct fire, and is cut into a number of fractions such as light oil, creosoting oil and naphthalene oil. The residue in the still is worked up then, according to the temperature of the distillation, into road compounds and pitches. The naphthalene oil fraction is chilled, and the naphthalene separated out in centrifugal machines. The light oil is washed with sulphuric acid and soda, and redistilled in stills provided with dephlegmating columns into crude benzols, toluols, etc. These are further redistilled to obtain the pure products.

The relations between tars from various sources as tested in this research are set forth in the following tables.

Comparative Ultimate Composition of Coal and Oil and Coal-Tar and Water Gas Tar.

	Coal.	Coal-tar.	Oil.	Water gas tar.
Carbon	82.47	89.21	84.28	92.70
Hydrogen	6.01	4.95	13.46	6.13
Oxygen	6.81	4.23	1.41	.69
Nitrogen	1.88	1.05	.24	.11
Sulphur	2.83	.56	trace	.37
Heating value, B.t.u's.	15353	15708	19200	17193

Comparative Distillations of Different Types of Tars.

	Horizontal.	Coke oven.	Vertical.	Water gas.
Start to 105°	0.4	1.0	0.1	1.1
Specific gravity at 25° C.	1.2039	1.1696	1.1302	1.0679
Free carbon, cold $C.S._2$	21.16%	9.36%	5.83%	.30%
Distillation, per cent. by weight—				
105–170°	1.4	0.3	1.1	2.8
170–225°	10.8	10.0	13.9	9.0
225–270°	10.1	12.4	12.5	12.6
270–300°	4.4	4.3	4.9	10.6
300–360°	4.6	3.0	1.5	7.9
Above 360°	20.4	28.0	27.3	30.4
Coke	46.5	40.6	35.5	25.4

Comparative Distillations of Three Types of Materials.

	Asphaltic oil.	Water gas tar.	Coal tar.
Specific gravity	.9177	1.1165	1.2090
Free carbon	.22	.90	19.80

Distillation—

	% by wt.	Gravity.	% by wt.	Gravity.	% by wt.	Gravity.
Start–110°	.32	.9105	.29	.9550	.52	.9862
110–170°	.75	.8215	1.44	.9637	3.06	1.0095
170–235°	6.25	.8436	14.61	.9900	13.39	1.0146
235–270°	23.51	.9604	24.05	1.0188	12.78	1.0357
270–315°	48.00	.8782	15.73	1.0422	10.57	1.0785
Residue	20.27	1.1471	43.31	1.2310	58.92	1.2850

The next table shows diagrammatically the products now commercially obtained from water gas tar.

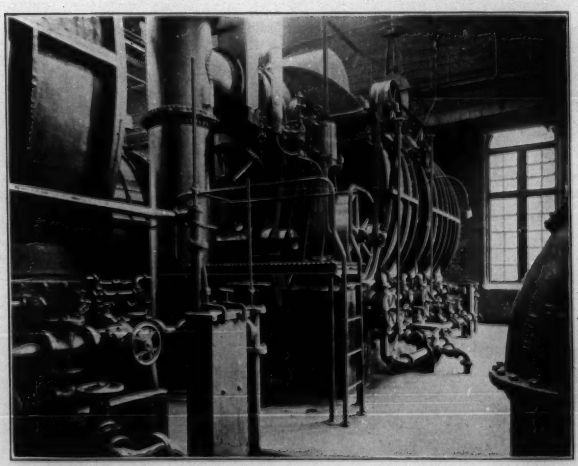
WATER GAS TAR PRODUCTS.

- Crude Water Gas Tar
  - Light Oil
    - Crude Benzol
      - Refined 90% Benzol.
        - C. P. Benzol.
        - Refined Special Fraction.
        - C. P. Toluol.
      - Residue
    - Crude Toluol
      - Refined Com. Toluol.
        - Refined Special Fraction.
        - C. P. Toluol.
        - Refined Solvent Naphtha.
      - Residue
    - Crude Solvent Naphtha
      - Refined Solvent Naphtha
      - Residue
    - Crude Heavy Naphtha
      - Refined Heavy Naphtha
      - Residue
  - Naphthalene Oil
    - Naphthalene Salts
    - Dead Oil
  - Dead Oil
  - Creosoting Oil
  - Road Compound
  - Pitch

Fig. 13.

Copperas mixing tanks.

Fig. 14.



Cyanogen washer.

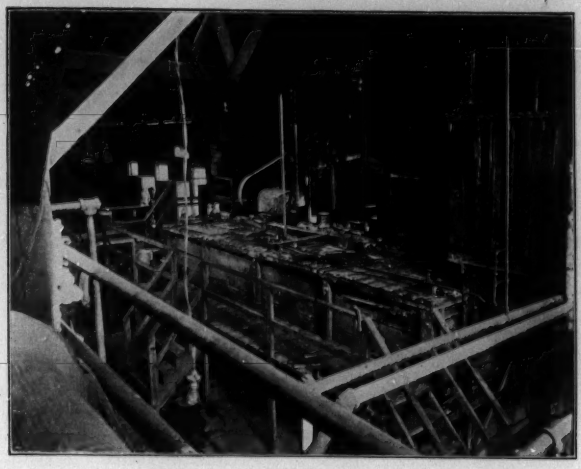
It seems a far cry from the distillation of gas from coal to the extraction of gold from its ores and yet industries as different as these two are correlated. To explain, it may be recalled that nitrogen has been found in the coal and that it appears combined in the by-products in many different ways. Among them it is found in the gas, the tar, the ammoniacal liquor, and, after the gas is purified, in the purifying material, combined with carbon to form cyanogen and cyanogen compounds, such as the ammonium salts, the thiocyanates, and others. And a large part of the metallic gold now extracted from low grade gold ores and tailings is, following the process devised by MacArthur and Forrest and modified by many others, dissolved out by aqueous solutions of the alkali cyanides which can be operated so economically that in certain localities ores containing so small a gold content as one dollar per ton can be worked to profit.

There have been many methods of cyanide recovery devised. These are described by Robine and Lenglen.[7] Among them is the Bueb process used to some extent in this country which consists briefly in scrubbing the gas, before its ammonia and sulphide is removed, with a solution of copperas whereby ammonium sulphate which remains in solution, and ferrous sulphide, which remains in suspension, are produced. The hydrogen cyanide and free ammonia in the gas now react with the ferrous sulphide giving ammonium ferrous ferrocyanide of the formula $(NH_4)_2FeFe(CN)_6$. Some of this double ferrocyanide may be converted into soluble ammonium ferrocyanide by the reagents present and to prevent this the "mud" is either boiled or made slightly acid with sulphuric acid.

In either case the insoluble double ferrocyanide is formed and the mud changes color from almost black to light yellow. The final products are an insoluble double ferrocyanide, and a solution of ammonium sulphate, which are separated from each other by filtration. The process has been found to work best at temperatures not exceeding 100° F. Under these conditions 90 to 100 per cent. of the total cyanogen is extracted. On a yield of 1¾ pounds of cyanogen per ton of coal carbonized, equivalent to about 110 grains of cyanogen per 100 cubic feet of gas the amount of copper as required theoretically is 6.3

[7] "Cyanide Industry." Trans. by J. A. LeClerc, with appendix by C. E. Munroe. John Wiley & Sons, New York, 1906.

Fig. 15.



Neutralizing tanks.

Fig. 16.

Top of neutralizing tanks.

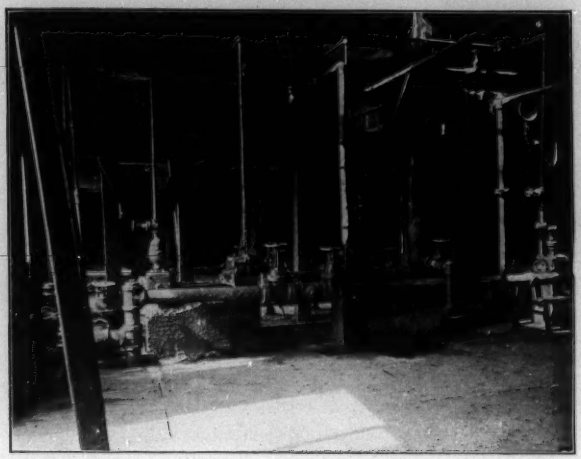
pounds and varies very little from this in practice. The ammonia absorbed in the process is equivalent to from 4 to 4.5 pounds of ammonium sulphate per ton of coal. About two-thirds of this appears as ammonium sulphate and one-third as insoluble ammonium compound in the press cake. The absorption of cyanogen by the Bueb method generally takes place in a standard washer. The gas should reach the washer freed from tar and at a temperature not over 100° F. The solution of copperas (ferrous sulphate) is run into the outlet end of the washer, where it is first converted into ferrous sulphide and ammonium sulphate. There is a tendency for the ferrous sulphide to adhere to and build up on the exposed surface. This would soon clog up the bundles in a standard washer, and for this reason the bundles in the last tray are replaced by large discs attached to the shaft and spaced about 3 inches apart. But even these gradually clog up and must be cleaned at times.

A device which kept the liquid in this chamber violently agitated would probably be preferable. In the original method of operating these washers the material was pumped forward from tray to tray whenever the first tray was saturated. This involved a great deal of pumping and it has been found that operating the washers on the same principle as an ammonia washer simplified the operation. The material in the inlet tray is tested from time to time by drawing off a small sample and acidifying with sulphuric acid. After stirring well a drop of this mud is put on a piece of white filter paper. Near it is put a drop of dilute ferric chloride solution so that the liquid from the two drops as they spread out on the paper will come together. A blue color occurring at the point where the drops meet is a sign that the mud contains an excess of ferrocyanide over iron and is therefore ready to be drawn off. If the material is saturated a slow stream of copperas solution is run into the outlet end of the washer. This forces the material in the different trays forward and the saturated acid overflows from the first tray. The copperas solution is kept running until the material in the first tray shows that it is no longer saturated.

In Germany the mud as it comes from the washers is generally sold to chemical works. At the Astoria plant of the Consolidated Gas Co. of New York mud is pumped into lead lined tanks heated to about 200° F. and acidified with sulphuric acid.

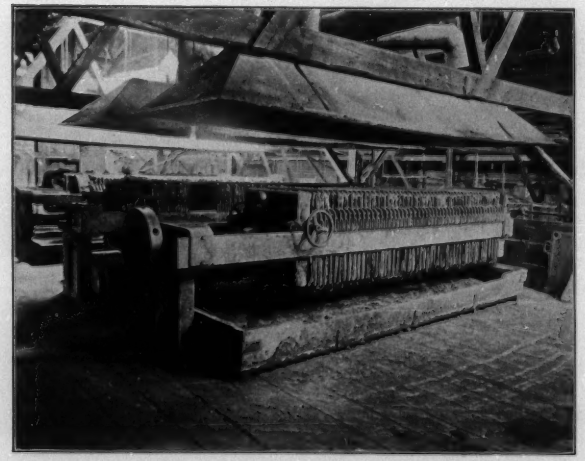
The addition of acid changes the color of the mud to light

Fig. 17.



High-pressure pumps.

Fig. 18.



Filter press ready for filling.

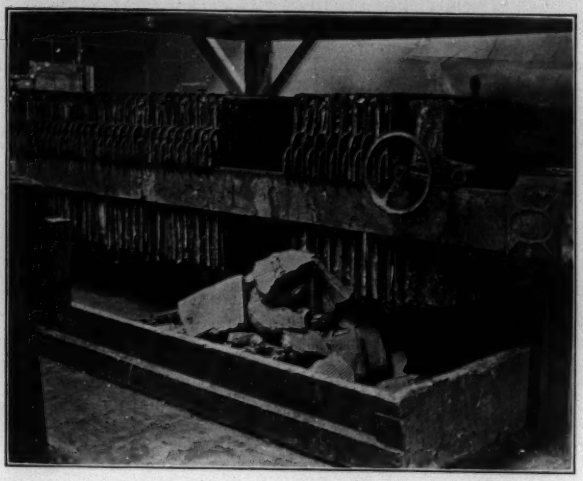
yellow. During this operation large quantities of hydrogen sulphide are set free and in order that this does not escape into the room the tanks are fitted with vent pipes connected to a fan which discharge the gases out of the building. Enough acid is used so that the material is slightly acid to litmus. The mud is again tested for soluble ferrocyanide with ferric chloride solution on a piece of white filter paper and if the blue color appears ferrous sulphate solution is added, a little at a time, until upon testing the blue color no longer appears. This converts all the cyanogen into an insoluble form.

The mud now consists of insoluble double ferrocyanide of ammonium and iron and a solution of ammonium sulphate with a little ferrous sulphate and very little free acid. This is pumped into filter presses (Fig. 18). After the press is full hot water is pumped through in order to wash as much as possible of the ammonium sulphate.

The wash water, which is a very dilute solution of ammonium sulphate, is used for making up the copperas solution. It is very difficult to wash out the ammonium sulphate. The best results are obtained by finishing the pressing with mud made by stirring up some of the finished press-cake with water until it disintegrates. The presses are about two-thirds filled with the neutralized mud from the washers and then finished with the mud made from the finished cake. In this way the gravity of the liquid coming from the presses is brought down from 8–10° Baumé to 1–2° before washing with water.

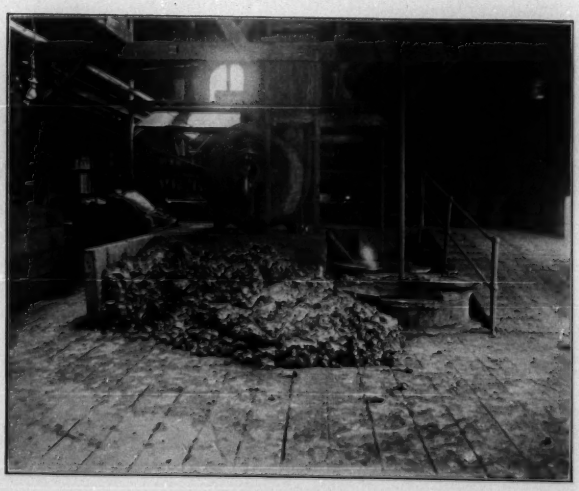
The solution of ammonium sulphate which runs from the filter presses is neutralized with ammonia. For this purpose some of the mud as it comes from the washers is boiled and the gases, principally ammonia and hydrogen sulphide, pass into the ammonium sulphate liquor from the presses. This not only neutralizes the free acid but also precipitates the small amount of iron present. This is necessary to avoid discoloration of the sulphate. The neutralized liquor is allowed to settle and the clear solution evaporated in lead lined pans. This solution contains approximately one pound of ammonium sulphate per gallon. The sulphate separates out on evaporation and is dried in a rotary drier (Fig. 24) by means of a current of air from a small blower heated by passing over steam radiators before passing through the drier. About 2.5 to 3 pounds of sulphate are produced per ton of coal carbonized.

Fig. 19.



Filter press partly opened and dumped.

Fig. 20.



Pile of press-cakes.

The cyanogen cake from the filter presses has approximately the following composition:

	Per cent.
Water	50 to 40
Cyanogen	22 to 28
Ammonia	5.3 to 7

About 6 pounds of press-cake are produced per ton of coal carbonized. When it first comes from the presses it is yellow in color, but on contact with air it rapidly turns deep blue to oxidation. It is sold to chemical works to be converted into sodium or potassium ferrocyanide. This is done by first distilling with lime which drives off the ammonia and forms calcium ferrocyanide. The solution of calcium ferrocyanide is filtered from the residue of iron hydroxide and is then treated with sodium or potassium carbonate, forming the corresponding ferrocyanide and calcium carbonate which settles out. The clear solution is then concentrated and the ferrocyanide crystallized.

Through the courtesy of Mr. Walter R. Addicks I am able to exhibit the following pictures of the cyanide recovery apparatus used in a gas works in this country.

No. 13—Shows tops of underground copperas mixing tanks with motor driven stirrers; copperas bins at the rear. Copperas solution is forced over to the cyanogen washers by steam pump on the left.

No. 14—Shows cyanogen washer which received the copperas solution from tanks shown in No. 13. After the copperas solution has extracted the CN from the gas it is returned to the factory in the form of cyanogen mud and stored in underground tanks under the filter press platform until ready to be worked up.

Nos. 15 and 16—Top of neutralizing tanks where the cyanogen mud is neutralized with sulphuric acid.

No. 17—Shows two of the five high pressure pumps which pump the mud from the neutralizing tanks through the filter presses.

No. 18—Shows filter press closed ready for filling.

No. 19—Shows filter press open and partly dumped; the press-cake is visible in the foreground.

No. 20—Shows pile of press-cake.

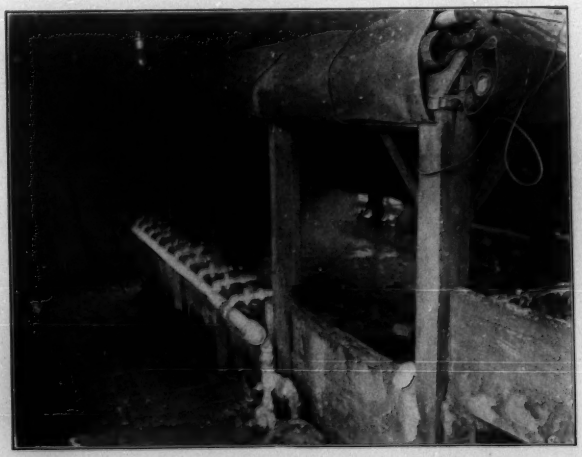
No. 21—Shows cyanogen press-cake bagged, ready for shipment.

No. 22—View of lead lined evaporating pan for sulphate

Fig. 21.

Cyanogen press-cake ready for shipment.

Fig. 22.



Evaporating pan.

liquor. Note steam header to the left, which is connected to lead pipe coils in bottom of pan.

No. 23—Shows ends of sulphate evaporating pans with piles of sulphate crystals on drain-boards.

No. 24—Shows rotary sulphate dryer with pile of sulphate under discharge end to left, and bags of sulphate in the foreground.

Unfortunately the demand for cyanides is not yet sufficiently large to warrant the cyanide recovery process being pushed very far.

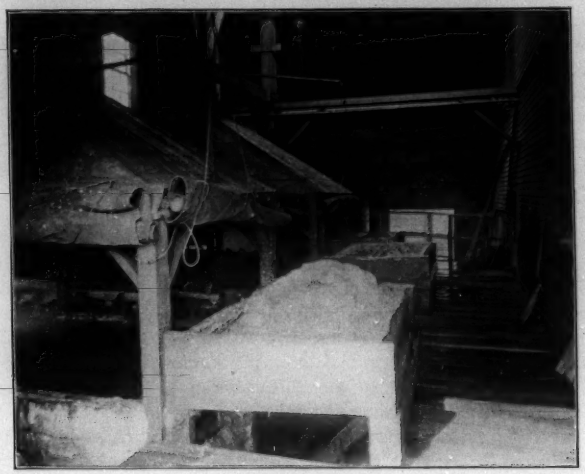
Another by-product which warrants further consideration is the spent oxide. Material rich in sulphur has been burnt in acid chambers and it has been proposed for use in copperas making. Two sulphur recovery processes which have been demonstrated as feasible and operative in the laboratory are now being tested on a commercial scale in the factories, Burkheiser's recovery process being operated in connection with the Flemalle Grande coke ovens near Liege, Belgium, while Walther Feld's rival process is being employed at the gas works in Konigsberg, Germany. Both aim to produce ammonium sulphate from the ammonium compounds in the gas liquor and the sulphur compounds obtained from the coal. Feld's process is of special interest to the theoretical chemist in that the formation of the commercial product sought and the saving of the useful matter accomplished is effected through the aid of the tetrathionates and the controlling under manufacturing conditions of the reactions through which they are formed and those into which they will enter.

It may perhaps be admissible for me in closing to refer to a scheme for gas making at the coal mine which has interested me much for a long time. I perhaps cannot better present the matter than by quoting from an address made to the American Institute of Chemical Engineers in 1909.[8]

"I have long looked upon our present custom of transporting coal long distances to be converted into gas as uneconomic, for a not inconsiderable quantity of coal is burned to provide the energy with which to haul this coal. Not only that but, since the gas constitutes but a very small percentage by weight of the coal, there is a considerable waste in hauling the coke, with its

[8] Trans. Am. Inst. Chem. Eng., 2, 100, 1909.

Fig. 23.



Sulphate evaporating pans.

Fig. 24.

Rotary sulphate dryer.

ash, and the by-products. Further, to provide for emergencies, large stocks of coal must be accumulated in advance at the gas works, and as coal, particularly gas coal, begins to deteriorate as soon as it is removed from the mine, there is a very considerable loss going on all the time from this cause. Further, as the by-products or residuals are now purchased in the crude states in relatively small quantities at the different gas works, a large part of their value is consumed in collecting and transporting them to central refineries.

"By producing the gas at the mine and shipping it by pipe line the cost of haulage of the coke, with its ash, and crude by-products is saved. The wastage of coal by weathering is saved. The cost of collection and transportation of the crude residuals is saved. Such coke as is not needed for industrial purposes can be converted in producers into gas which, by means of internal-combustion engines, can be used in generating electricity for distribution, and the ash from this coal can be put into the mine for use as a filler in place of coal.

"It is evident that gas can, under these circumstances, be made and delivered at a much less cost than is the case at present, though it may be necessary after long travel to enrich it near the point of consumption. Furthermore, the valuable areas now occupied by gas plants in our cities can be given up to more concentrated industries and cheap country lands be substituted for them."

The pertinency of this proposed scheme to the topic given me for consideration lies in the improved opportunity which this plan would afford for the utilization of the by-products, and I foresee that should this plan of gas generation at the mine ever be realized there would grow up about the gas generating plant a large number of industries based upon the utilization and further manufacture of the by-products, and that they would be greatly fostered, as would many other industries, by the very cheap gas, which could, under these circumstances, be produced for use as a source of heat, power or light, and which could be so cheaply produced as to enter, on the spot, into competition with water power as a source of electric energy. It is of interest to note that Sir William Ramsey has recently given this suggestion of carrying on the manufacture of gas at the coal mine his endorsement.

RECENT DEVELOPMENT OF THE LOCOMOTIVE.[1]

BY

GEORGE R. HENDERSON,

Consulting Engineer, The Baldwin Locomotive Works, Philadelphia.

SIZE AND POWER.

TEN or twelve years ago the steam locomotive had assumed such proportions that it was thought by many engineers that the limits of size and capacity had been practically reached. The increase in weight had been going on steadily for years, but with comparatively few advances that, at a single bound, were remarkably in excess of what had previously been done. About this time, however, a number of circumstances occurred which made it absolutely imperative that more powerful locomotives be obtained, and these last ten years have produced different reasons for increasing the power of the locomotive, treading fast one upon the other.

The advent of large-capacity freight cars has resulted in a train that could be more easily handled with a large tonnage than it could be in the old cars of less capacity, as the train length is shorter and the number of cars in the train considerably diminished for a given tonnage, which is a very important factor in connection with the proper operation of the brakes when descending grades. Instead of cars of 30 tons capacity, which were the common maximum a decade since, 50-ton cars are now very plentiful, and even cars of 75 or 80 ton's carrying capacity are being seriously considered. This means that for a train of the same number of cars double the tonnage can be hauled and a more powerful locomotive can be economically used.

The introduction of steel passenger equipment, with a view to eliminating many of the horrors of fire and collision, also calls for more powerful locomotives, as the weight of these cars has been very considerably increased. In olden times a 60-ton car was considered a very heavy vehicle, but nowadays 75 tons is not at all abnormal, and a weight of 90 tons has been reached.

[1] Presented at the Stated Meeting held Wednesday, April 17, 1912.

The agitation for increase in wages of all men connected with the transportation department of railroads has been more or less generally successful, and in order to offset, to some extent, these increased expenditures, reduction in operating expense has been necessary. This is brought about very largely by the increased capacity of the locomotive. As an example of what can be done in this line, some years ago a road with which the writer was connected found, by the purchase of some passenger locomotives of considerably greater power than heretofore used, that each of these engines in the first year during which they were operated saved $5,000 in reducing the expense incidental to double-heading trains and running two sections, where the necessary cars could be handled by one of the new engines.

The increase in traffic due to the natural increase in population, which has for the United States amounted to 20 per cent. in the last ten years, has in many cases called for either double-tracking, large additions for side tracks, or other provisions for handling an increased movement of tonnage over and above what could be arranged with the old facilities. With an increase in the power of the engine it is possible not only to handle tonnage more cheaply, but to handle a larger amount without any additional efforts in the way of dispatching or interference with other trains; for instance, if we could double the train load, we could practically move twice the amount of tonnage without increasing the number of meet orders or delaying trains in the opposite direction. On this account alone the large locomotive has been invaluable in enabling the companies to increase very greatly their tonnage without having to make large expenditures for improvement in tracking facilities, greater number of sidings, extra track, etc., and this has been no small part of the burden removed, although we do not hear as much said about this part of the operating problem as some of the others which we have mentioned.

The more recent decision of the Interstate Commerce Commission that the railroads should economize instead of increasing their rates calls for an additional effort in this line, and these cumulative experiences, coming closely one upon the other, within the past decade have brought about a locomotive of size and power which was not even dreamed of ten years ago.

The electric locomotive has made its appearance and has

done very good work in certain localities, and in order to compete with such an engine, which has the output of a large stationary power-house behind it, the steam locomotive has had to increase its capability for exerting power. For years the clearance or height and width possible for locomotives, owing to the outlines of tunnels, heights of bridges, proximity of station platforms, buildings, etc., has prevented any considerable increase in these two directions, so that the remaining dimension, viz., that of length, was the one direction in which increases could be made. This has brought about, naturally, engines of long wheel base with long boilers, and, while a few years ago tubes of 16 feet length were considered as quite long enough for good design, we now find them extended to as much as 25 feet, and the end is probably not yet. Of course, these increases in size mean increase in weight, which, while it is a natural consequence of the increase in power, is also necessary to provide sufficient adhesion to make use of this increase in power. This, however, means necessity for heavier track and bridges, and, in order to reduce the load on track and bridges as much as possible, the extension of this weight into increased length has helped to keep down the weight per lineal foot. This however, is increasing, as, while a few years ago 25 tons was thought to be a very large weight on one pair of drivers, 30 tons is now very frequently considered, and is, in fact, already exceeded in a few cases.

The question of longer boilers and longer engines leads us to a good many complications which have heretofore been avoided. While boiler flues have been used up to 25 feet in length, this is about the limit at which the mills are able to roll them, and besides, it is considered wise not to increase the lengths too greatly without having experience of gradual extensions. The new lengths of locomotives in many cases require, for structural reasons, if nothing else, a barrel as great as 53 feet, and, in order to fill up this space, there have been various means adopted to supplement the length of the flues. Combustion chambers extending from the fire-box forward, a distance of 5 or 6 feet, have been introduced, and the amount of boiler has been utilized for feed-water heaters, reheaters, superheaters, and other devices, all of which tend toward economical operation and make good use of the extra length of boiler shell. These

different devices will be referred to more in detail later on, but the reasons for their existence and for having space to apply them, which we did not have some years ago, should be considered at the present time.

The lengthening of the boiler and the engine means that flexible wheel bases must be introduced. The favorite type of long, rigid wheel base engine has generally been the consolidation, consisting of one pair of truck wheels and four pairs of driving wheels; to this, later on, a trailing truck was added, giving us the 2–8–2, or Mikado type of engine. There were several reasons for the introduction of this type; probably the first one was to provide an engine which could be backed around curves and switches as easily as run forward. Consolidation engines have been in the past very largely used as helper locomotives, and, after helping a train up a mountain for ten or twenty miles, it was often desirable to back them down hill to be ready for the next ascent. If the road was crooked, derailments were likely to occur when having only a driving wheel to negotiate curves. The trailing truck, therefore, was originally introduced to enable these engines to operate with equal satisfaction around sharp curves in either a forward or backward direction. The construction of boiler was kept very similar to the Consolidation engine; that is, the fire-box was above the rear drivers and the rear truck was purely for guiding purposes.

With the desire for additional heating surface requisite for maintaining higher speeds, it was found that advantage could be taken of the trailing truck to bring the fire-box entirely back of the drivers and thereby make it deeper, as the truck wheel was so much lower than the drivers. This gave longer tubes and a better fire-box for the proper combustion of fuel, and the increase in fire-box volume and heating surface has been considered so essential that nowadays the Mikado engine is used for road service, principally on account of the large boiler capacity which can be obtained thereby.

In the same way that the Consolidation locomotive was developed into the Mikado type, the Pacific locomotive was the outcome of the ten-wheel engine. In the olden times the ten-wheel engine was built with a deep fire-box between the frames and between the middle and rear driving axles, but, with the increase in dimensions necessary for modern locomotives, this

space was too much restricted and the fire-box was raised entirely above the rear drivers. For the low wheels in freight service this answered well enough, but when it came to passenger engines with wheels from 70 inches to 80 inches in diameter the boiler was raised very high and there was little depth of fire-box possible. The addition of the trailing truck to this type of engine, therefore, allowed a deep fire-box and also a wide one by extending the boiler backwards until the fire-box was entirely in the rear of the driving wheels. This is illustrated by Fig. 1.

The Pacific type of locomotive may also be, in a measure, considered the logical development of the Atlantic type of engine, which first made its appearance about fifteen years ago. The original engine of this wheel arrangement was constructed for the Atlantic Coast Line in 1895, and was simply a ten-wheel engine with the rear driver changed to a trailing wheel in order to give room for a deep and longer fire-box, which could not be obtained with the regular high driving axle at the rear. The particular object to be obtained in this case was an increase in steaming power to haul at greater speed heavy trains which were needed for carrying the passenger traffic at that time. This engine, it will be noted, was not provided with a trailing truck, but the trailing wheels were simply placed in pedestals and located at about the same place where the third pair of drivers would have been in a ten-wheel type of locomotive. In this case it was not a question of adhesion so much as the possibilities of sustained horsepower at high speeds, and, as the tractive force of a locomotive always diminishes as the speed increases, the maximum adhesion is never used, except in starting and at very slow speeds.

The Pacific type of locomotive has become particularly popular for high-speed freight and heavy passenger service, and might now almost be considered the standard type of passenger locomotive used in this country for heavy trains at high speeds. For steep grades the Mikado type of engine has been used very successfully in passenger service, particularly on the Union Pacific Railroad, by making the driving wheels sufficiently large for the purpose intended and keeping the fire-box over the rear truck, as shown by Fig. 2.

It has been a general axiom in locomotive construction that the diameter of the driving wheels in inches should be as great

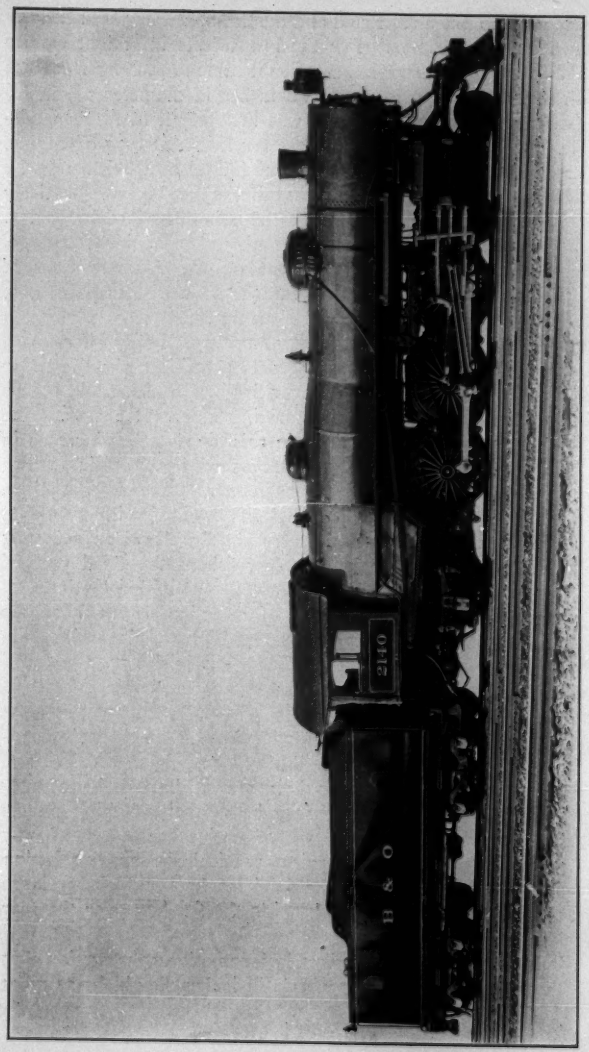


FIG. 1.

Pacific type locomotive.

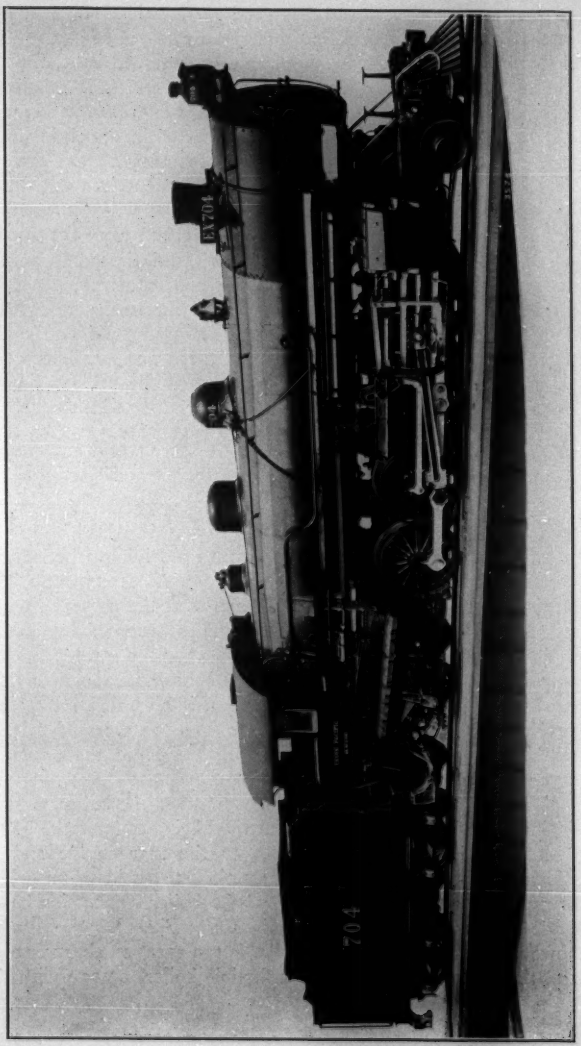


FIG. 2.

Mikado type passenger locomotive.

as the maximum speed in miles per hour at which the engine is intended to run, this resulting in a speed rotation of 336 revolutions per minute when the speed above mentioned is attained.

In 1903 the Santa Fe type of engine, which is a 2–10–2 locomotive, was introduced, and which was really a Mikado engine with an extra pair of drivers inserted in the rigid wheel base. While it is the practice in this country to use flanged tires on all the drivers of Consolidation locomotives and those having a less number of driving wheels, yet when it came to the five pairs of drivers the flange was omitted from the middle wheel. It had been the custom to use bald tires on Consolidation locomotives, but experience later demonstrated that by placing the tires of the front and back wheels closer together than the middle wheels the tire wear was more uniformly distributed over the different wheels and there was no difficulty in passing curves of fairly sharp radius. At the present time a locomotive of the 2–10–2 type with 30-inch by 32-inch cylinders is being built, reviving the Santa Fe type of nine years ago. These latter engines will be used on the Chicago, Burlington and Quincy Railroad.

It seems, however, as if this was the greatest aggregation of driving wheels that could be used in a rigid wheel base, and when it is desired to use more than ten driving wheels it is necessary to go into the Articulated type of locomotive. The particular style most used in this country at the present time is termed the "Mallet," as it was originally proposed by M. A. Mallet, of Paris. In this device there are four cylinders, each pair operating a set of driving wheels in individual frames, the two sets being connected together by a hinged joint. This enables an engine with six, eight, or even ten pairs of driving wheels to pass curves with no more resistance than engines heretofore employed.

There have been two ways of connecting the boiler to such engines and frames, the original method being to have the boiler with a rigid shell firmly attached to the rear engine and to allow the front, or low pressure section, to oscillate and slide transversely under the front end of the boiler, connection being made by means of flexible steam pipes (see Fig. 3). Sometimes, however, the overhang of the boiler is too great on sharp curves, and then recourse is had to the flexible boiler, or one with the

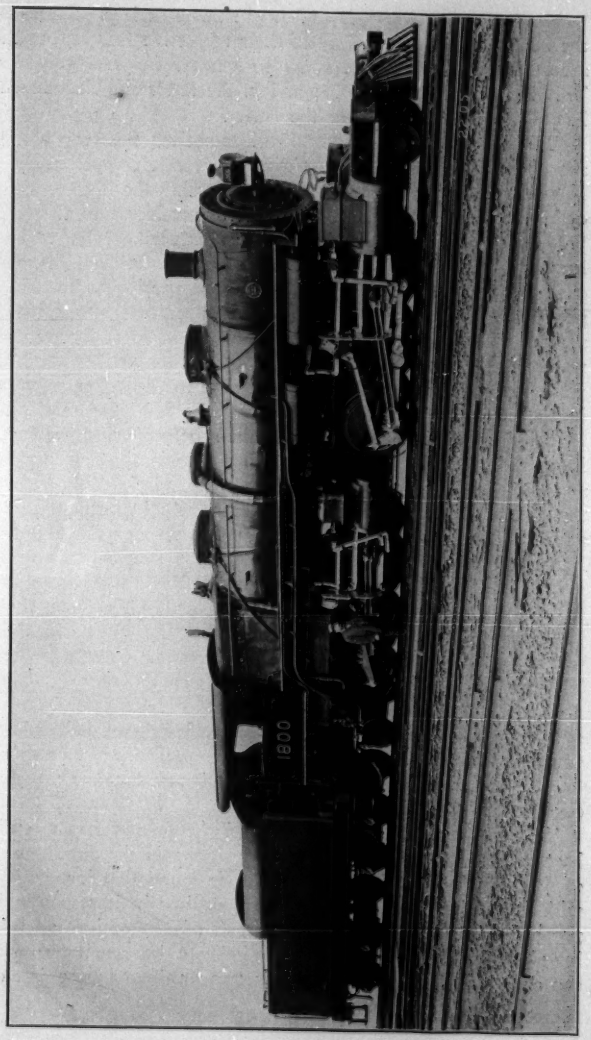


FIG. 3.

Mallet locomotive.

"accordion" joint, as it is called. In this case both sections of the boiler are secured rigidly to their respective frames, but the accordion joint allows the boiler to bend when passing curves. This is illustrated by Figs. 4 and 5, the latter showing an enlarged view of the joint in the boiler.

In both these types of Mallet locomotives the rear wheels are operated by high-pressure cylinders receiving steam direct from the boiler, and this steam, after passing the high-pressure cylinders, goes through an intermediate receiver into the low-pressure cylinders, and finally to the exhaust. The various heaters of which we have above spoken are utilized in some cases, first, to superheat the steam before passing to the high-pressure cylinders, and, secondly, to reheat the steam in its passage from the high- to the low-pressure cylinders. The feed-water heater at the front end has been used to abstract heat from the gases during their last passage in the boiler so as to increase the temperature of the water and bring it practically up to a boiling point (at boiler pressure) before being delivered into the boiler proper. These various combinations of heaters and compound cylinders, of course, very considerably reduce the fuel consumption, which is an extremely important factor, now that the boilers have assumed such enormous size. It has been found by experience that an ordinary fireman cannot, as a regular performance, put in the fire-box more than from five to six thousand pounds of coal an hour, and, while for a short period some good men can exceed this rate, yet, ordinarily, it is unwise to expect him to handle more than this amount of fuel. The compound principle generally effects an economy of about 20 per cent., and as superheaters, reheaters, feed-water heaters, etc., may give as much more, it is plain that these devices have enabled us to get more power out of a locomotive fired by a single fireman than would be possible with ordinary simple expansion engines without the devices referred to.

The limit of physical endurance of the fireman has recently been recognized as the actual limiting factor in the development of power by a large locomotive, as it is found that locomotives with increasing size do not develop ordinarily horsepower in proportion to that size. Repeated tests of locomotives on testing plants and also in actual service indicate that one horsepower can ordinarily be obtained by from two or three square feet of

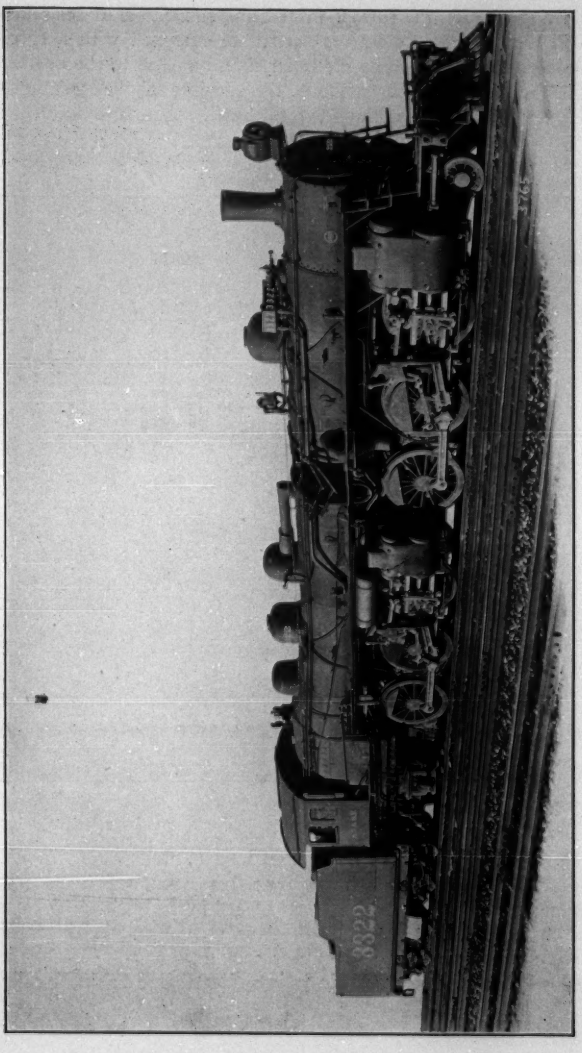
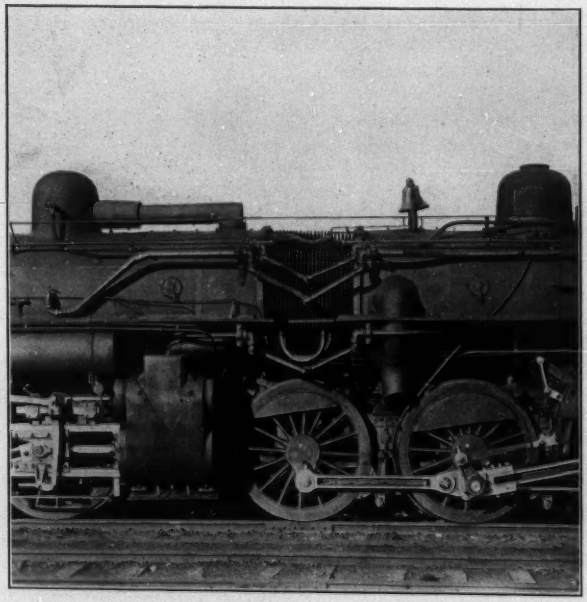


FIG. 4.

Flexible boiler Mallet locomotive.

heating surface, the former value being susceptible of attainment with compound locomotives and those equipped with a special economical device, while the latter figure applies to the ordinary saturated locomotive without the devices above mentioned. Under ordinary conditions the saturated steam locomotive will

FIG. 5.



"Accordion joint."

develop a horsepower with about four to five pounds of coal per hour, and for 1,000 horsepower there would be very nearly as much coal required as could be placed by an ordinary fireman. With compound engines, superheaters, etc., of course, the capacity of the fireman in horsepower can be very considerably increased, as above noted, but it is a fact that even locomotives

with 5,000 or 6,000 square feet of heating surface often deliver only about 1,200 or 1,500 horsepower. This limitation of the steaming capacity, due to the human element of the fireman, has brought about the investigation and introduction of mechanical stokers, of which more will be said anon, but it is here mentioned in order to account for the extreme sizes of locomotives that have been proposed, as well as some actually under construction. Of course, the same limitations do not apply to locomotives which burn oil, as there is no difficulty in getting sufficient oil in the fire-box for practically any reasonable rate of combustion, and some of the largest engines heretofore built have been arranged to burn liquid fuel. This is notably true of the southwestern part of this country, where the oil fields in Texas and California furnish a fuel that, in addition to overcoming the limits of physical endurance of the fireman, also enables steam to be generated at a cost considerably below that for coal. This is illustrated by the Southern Pacific locomotive in Fig. 6.

Following these lines of increase, locomotives of more than two sections have been proposed in some cases in which the successive engines have received the steam in sequence, so as to form in effect a triple-expansion engine, and in other cases in which the steam has an expansive ratio of 2 obtained by exhausting from one pair of cylinders into two others. In order to keep down the length of the engine within reasonable limits, the tender can be made to do its share of the work, and, without increasing the length and only slightly the weight and expense, a locomotive can be constructed having about 50 per cent. more hauling capacity than a heavy Mallet type of locomotive as now in use.

The Mallet locomotive is no experiment, as many hundreds of them are in use in this country, but the triplex Mallets are still a problem for speculation and production. The first compound locomotive built by the Baldwin Locomotive Works was constructed in 1889, and, while the compound type of locomotive for a few years alter this was very strenuously sought on account of its fuel economy, it was found that there were other objections which, in many cases, overcame the benefits of reduced fuel consumption. With the introduction of the Mallet locomotive, however, the compound feature is of great importance. first.

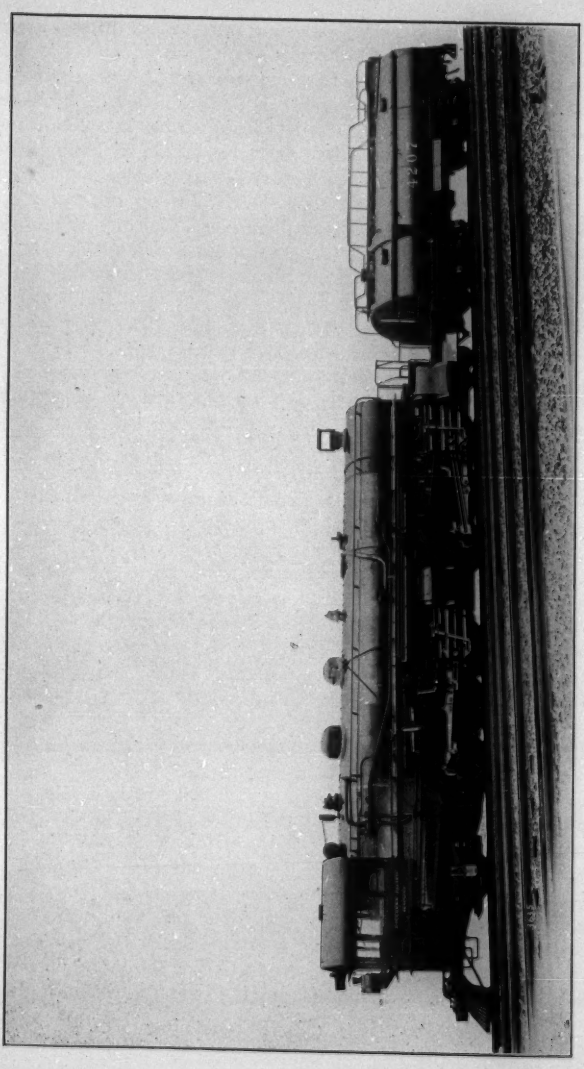


FIG. 6.

Oil-burning Mallet locomotive.

as it reduces the amount of fuel needed to produce a given amount of power, thereby enabling a large locomotive to be successfully handled by an ordinary fireman, and, secondly, that the pressure of steam passing through the flexible joints is only about one-third of the boiler pressure, thereby reducing the difficulty of keeping these joints tight. When this type of engine was first placed in service it was feared that these ball joints would cause considerable difficulty, and, while some trouble has been found, this is being largely overcome as the round-house men become more familiar with the engines and expert in the packing of these joints.

There has been a type of locomotive introduced by the Borsig Company of Germany in which there are flexible wheels, these being mounted on tubular shafts through which the driving axle passes, so that, while the axles themselves are held in rigid boxes and operated from one pair of cylinders, the wheels can slide and swivel to adjust themselves to different degrees of curvature. We understand that these engines have given good service in certain localities in Europe, but we do not think that any of them have been introduced into this country.

ADJUNCTS AND DETAILS.

It is probably true that cast steel is more closely connected with the development of the large locomotive than any other single item entering into locomotive construction, and the possibility of being able to get large castings in this material has proved a very important factor in the advancement of this proposition. Some years ago steel castings were produced only in very small sizes by means of crucible furnaces, and such things as steel driving wheels, frames, foot-plates, etc., were unknown. With the large number of open-hearth steel plants making steel castings of high-grade material now in this country, there has been a great impetus given to the reduction of weight and increase of strength by substituting steel castings for iron castings and, in many cases, for iron forgings. In the former category probably driving wheel centres have been the most conspicuous examples, as even ten or fifteen years ago the axles and crank-pins of locomotives were assuming such proportions that it made it difficult to obtain the proper strength with an iron casting. As the main driving wheel is subjected to a far greater stress

than the other driving wheels, steel was first substituted in the main driving wheel only, but nowadays, when it is desirable to get the boiler as large as possible and thereby keep the other parts as light as possible, cast steel is used in many cases in all the wheels of a locomotive. It has now even become difficult to get along with cast steel, as, with the increased size of axles and pins and the inadvisability of increasing the stroke, we have gotten to such a point where there remains only 5 inches or 6 inches of metal between the axle and the pin fits, and when we consider that these are forced in with pressures from 100 to 200 tons it will be understood how difficult it is to produce a steel casting that will satisfactorily withstand forcing stresses and also those due to operation.

At first there was much difficulty in making driving wheels, as the rim would set in the mold long before the hub and fractured spokes would occur. This was overcome by separating the rim into sections so that the spokes could pull the rim towards the centre as cooling progressed. Later, however, the steel works found that they could cast these rims solid by uncovering the hub and arrange to cool that portion more rapidly so as to promote uniform contraction throughout the casting.

Foot-plates have been another very important example of the use of steel instead of iron castings. In olden times the foot-plate was often made unusually massive in order to add adhesive weight to the engine, but the great desire to produce boilers of maximum capacity has led to the use of foot-plates of cast steel, thereby reducing the weight very materially and allowing for greater boiler capacity. In such castings as these the weight of the piece in steel would be anywhere from one-half to one-third of what it would be in cast iron, and when this practice is followed through the different parts of the engine the great saving of weight is at once apparent.

Boiler supports, guide yokes, frame separators, and, in the Mallet type of locomotive, saddles connecting the frames and the cylinders, are now made of steel castings, and this metal is very much superior to iron in standing impact and even the effects of an unexpected collision.

In the replacement of forgings, cast steel has also rendered an important service; the most notable example of this is in locomotive frames. For years these were made of iron worked

under the steam hammer, and, as the frames were of large sections, it was very difficult to properly weld the pedestals and braces together. When the sections were not over 4 inches in thickness there was little difficulty, but even then it was found that the welds, in spite of the best care, had often been imperfectly formed and would in service pull apart. With 5-inch frames, which are now common, and 6-inch frames, which are being introduced, this work would be very difficult, but cast steel permits the use of a section of almost any size. Then, too, the braces and all the parts are cast in one solid piece, so that there is less fitting and less opportunity for parts to become loose and work upon each other when the engine is in operation. Many of the more complicated forgings, such as equalizer beams, frame braces, and parts that have been made in the blacksmith shop, are now constructed of cast steel, often reducing the weight and at the same time the cost of manufacture.

In this country open-hearth steel is used almost exclusively for this material, but in Europe Bessemer steel with a comparatively high phosphorus content is much in vogue. This makes a smoother casting, as the phosphorus adds to the fluidity of the metal when being poured, but Americans are rather opposed to the use of Bessemer steel in important structures on account of its known liability to segregation and to crack under sudden strains. The open-hearth steel used for locomotive castings is both acid and basic, the former, of course, requiring a higher grade of pig to be used in its production. The great difficulty with steel castings at the present time is the tendency for piping and blow-holes to diminish the strength of a section at some part where it is impossible of detection before rupture, and, while this difficulty is being gradually reduced, largely by the careful study of proper design and the introduction of large sinking heads in molding, yet it must still be contended with and prevents us from using as high a fibre stress as we should if we could get rid of these objectionable features. Such steel has a tensile strength of from 60,000 to 80,000 pounds, which is fully double what can be obtained from cast iron, and, on account of its ductility and resistance to stand blows, it is superior to cast iron in even greater proportion than its increase in strength.

As yet little has been done in the use of cast steel cylinders in locomotives, although some few have been in service. As

there is a tendency toward three-part cylinders—that is, a central saddle with a separate cylinder bolted at each side—the feasibility of using steel cylinders has been greatly enhanced. Of course, such cylinders have bushings of cast iron for both the piston and the valve, and, as the latter is nearly always of the piston type, the construction of a cylinder of cast steel is not especially difficult. The recent practice of using outside steam pipes materially assists in this problem.

Following the introduction of steel castings for frames, driving wheels, driving boxes, etc., alloy steel has also made its appearance in locomotive construction, and chrome vanadium or chrome titanium is frequently possible for the parts involving heavy stresses. The latter adds very little to the cost of steel per ton, and is thought by some to be practically as efficient as the high-priced vanadium steel. Nevertheless, there is difficulty being experienced, with both of these alloys, and when we consider that even the heaviest sections that we are able to produce now are hardly strong enough to stand such enormous piston loads, which in some cases reach to 140,000 or 150,000 pounds, the necessity for refinement in this line is apparent.

There has been little attempt to make such parts as connecting rods, parallel rods, etc., of steel castings, and the few attempts that have been made in this line have not been crowned with sufficient success to warrant extension in these particular details. Crank axles are seldom used in this country, but it has been found that the crank-webs in a built-up axle have given very good service when made of cast steel, but the forces in such a structure produce, principally, bending and torsion where steel castings are particularly satisfactory. In connecting rods, however, there is so much tension and compression that it does not seem wise to run the risk of using a metal that may have a blow-hole or pipe at some critical part, and only high-grade hammered steel is used, as a rule, in these forgings.

While the Walschaerts valve motion has been recognized for many years as a suitable means for operating the valves on a locomotive, and has been used largely in Europe, it is only recently that its application to locomotives in this country has been worked out on a large scale. There have been many essays written upon the relative advantages of the Stephenson, which has been universally used, and the Walschaerts valve motion, so

far as the movement of the valve itself is concerned, some claiming the Walschaerts gear with its constant lead was a great benefit, while others claim that the Stephenson motion with its increasing lead for early cut-offs is most desirable. Personally, we are inclined to agree with the latter theory. It is well known that a locomotive with a large amount of lead is very slow in starting, whereas one with a small or blind lead will be particularly active in getting under way and being reversed. With the constant lead of the Walschaerts motion it is necessary to settle upon some amount that will be satisfactory under ordinary running conditions, and this often produces a locomotive that is noticeably tardy in handling. In the Stephenson motion it is perfectly feasible, if desired, to set the valves line and line when the reverse lever is in the corner and have from ¼ inch to ⅜ inches lead when working at early cut-offs. This in itself constitutes a considerable advantage; however, it has been found by practical demonstration in road tests that there is no essential difference in either fuel economy or economy of train operation between the two methods of distribution, and for all practical purposes we can generally assume that the steam distribution and economy will be the same in both.

What, then, has given the impetus to the Walschaerts gear within the last decade, if there is no advantage to the valve movement, and, in fact, the possibility of a disadvantage? The answer is that it is simply caused by structural reasons. The Stephenson motion, with its inside links, while being well protected from damage by a side-swipe, has the disadvantage of requiring eccentrics, which, with the modern proportions of driving axles, have assumed very large dimensions, so large, in fact, that there is continual trouble in trying to keep them lubricated, as the weight and speed of the running surfaces have been increased with the enlargement of the axles. There is also considerable difficulty in suspending the link centrally, and, while it could be done, it was rather a troublesome and expensive arrangement. Perhaps the greatest incentive to remove the valve motion from under the barrel of the boiler was the fact that the heavy engines with long frames required cross-bracing, and when the eccentrics and rods are removed we have splendid opportunities for connecting together the frames with ample cross-braces. The increased weights have called for wider frames and long journals,

so that there is very little space left in which to place a satisfactory inside link motion.

The Walschaerts gear overcomes both of these difficulties, permitting not only a very comprehensive system of cross-bracing, if desired, but also eliminates the eccentrics and places the motion where it is very accessible. It has been claimed that the Walschaerts valve gear has fewer pieces and weighs less than the Stephenson, but when we consider the supports necessary to carry and suspend the various parts of the Walschaerts gear there is a great deal of weight and expense which, while it is not a part directly of the valve gear, yet is necessary to support the same. This results in an increased cost for the Walschaerts as compared with the Stephenson valve gear. In many cases these supports can be worked in as part of or an extension of the cross-bracing of the frames and boiler and produce a very simple and strong structure, and, taking everything into consideration, the change in valve gear has resulted in a very much better braced engine than was possible with the old Stephenson motion. There is no question, therefore, but that this valve motion is here to stay, in spite of the fact that many people consider the actual movement of the valve not as satisfactory as with the Stephenson arrangement.

With the large and heavy valves that must be moved in the modern locomotive the force necessary to operate the reverse lever has considerably increased. With articulated locomotives, which have two or more shifting valve motions, the work to be done is doubled or trebled; therefore, we are prepared to understand the second advent of power-reversing gears. It has probably been thirty years since the first steam reversing gear was used in this country, after a few years' use of which on a very small number of locomotives it was abandoned. In those days the valves were small and there was no difficulty in handling them very satisfactorily with the reversing lever. Now, however, the conditions are entirely different, and, in addition to the heavy weights to be moved, the wide fire-box prevents in many cases a good practical application of the time-honored reverse lever. In some cases it has been necessary to use a power reverse simply because a satisfactory hand reverse lever could not be worked in with the type of boiler used. These considerations are of sufficient importance to necessitate the complication of the power reverse gear, so that it is not likely that it will be relegated to oblivion, as was the attempt made many years ago.

There are several types of power-reversing gears, but we believe that the type in which the movements of the engineer resemble those of the ordinary reverse lever are most desirable, particularly when engines are placed in the chain gang and are not operated with a single crew. Thus, in the reversing gear which is illustrated by Fig. 7, the engineer simply pushes a small lever to the desired position and the reversing engine automatically moves the valve motion until it has assumed a position corresponding to the hand lever, and, while this hand lever may be reversed with a very rapid movement, yet the engine itself will pull the motion back slowly but surely, regardless of the speed with which the engineer has moved the controlling lever.

While piston valves have long been used in marine engineering, the general use of them in locomotives dates back a little more than ten years. The Vauclain compound locomotive with the high- and low-pressure cylinders superimposed, one above the other, was operated by a single piston valve for the two cylinders, this reducing the mechanism to a much simpler form than could be accomplished by means of slide valves. Previous to this there had been very few engines of the simple type equipped with piston valves, but the success which attended the use of the piston valve with the Vauclain compound induced its extension upon locomotives operated by single expansion only.

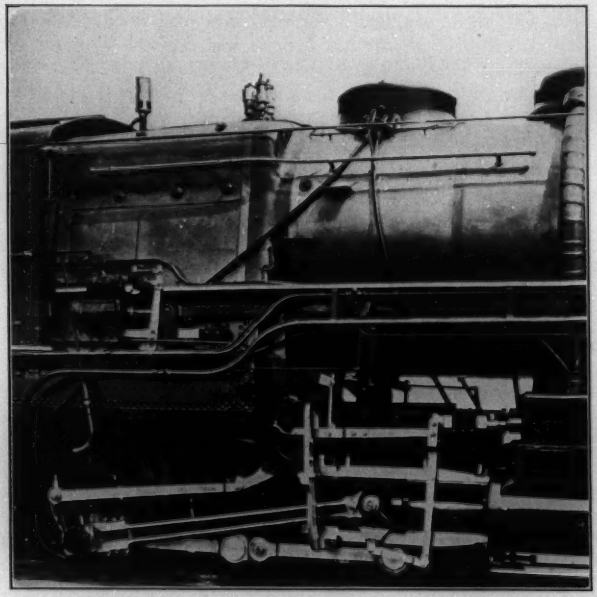
When the piston valve is used to replace an ordinary slide valve it is of a very simple type, and is practically a slide valve extended into a circle, with packing rings used at the several steam and exhaust edges. There has been considerable discussion as to the value of these valves as compared with slide valves, and a number of tests have been made, some showing better for one, some showing more economy for the other. There is little doubt but what this question of economy depends greatly upon the maintenance of the valve and the condition in which it is allowed to run, as a leaky valve of either type would, of course, be very wasteful of steam.

One of the principal advantages of the piston valve is the fact that it is fully balanced and easier to manipulate the engine than with a slide valve, even of the balanced type. As a matter of fact, piston valves are generally manipulated with greater ease when the throttle is open than when it is closed; still, the converse is true of balanced slide valves.

In spite of the fact that there is some doubt as to whether

the piston valve is really more economical in steam consumption than the slide valve, yet they have been introduced in great numbers, parly due, no doubt, to the fact that the large cylinders require large ports, and the port opening with the piston valve can be made nearly double that possible with an ordinary slide

FIG 7.



Power reverse gear.

valve. The large valves also are very little harder to handle in the cab than those of smaller diameter. Another advantage lies in the fact that piston valves can be, and generally are, so designed that the steam enters at the centre, or central admission, as it is called, and exhausts into the ends of the chamber, the valve being hollow, permitting both ends of the steam chest or valve chamber

to be in communication with each other. This reduces the pressure on the valve stem packing to that of exhaust steam only, and when it is considered that the variable travel of the valve makes it much more difficult to maintain packing on the valve rod than on the piston rod, which always travels the same distance and forms no intermediate shoulders, the advantage in relieving this packing of high pressure steam will be at once appreciated.

Reference was made above to the fact that in the Vauclain compound of the superimposed cylinder type one valve was able to regulate the admission of steam to both cylinders. In this case both the pistons worked together, being attached to the same crosshead. A later type of the balanced compound, in which the pistons move in opposite directions, has also been successfully worked by one valve, resulting in extremely simple mechanism for this type of engine.

The advantages of the Allen ported slide valve for the quicker admission of steam to the cylinders has long been appreciated, but this has not been generally introduced into piston valves, one reason, no doubt, being due to the fact that the much larger valve opening, on account of the greater length of port, made it unnecessary. With the increasing size of cylinders and the greater speeds at which it is desired to operate large tractive forces, it becomes necessary to adopt a somewhat similar arrangement for piston valves. This has been developed into the double ported piston valve, whereby there are two ports or openings, both for steam and for exhaust. The advantage of this is that a higher steam line or pressure line can be maintained in the cylinder up to the point of cut-off and less back pressure during the period of exhaust, as the steam has twice the area of opening when near the points of port opening and closure than could be obtained with an ordinary valve of the same size. As this port is placed partially in the valve chamber bushing, there is little additional complication added, except in making the valve itself, but the cylinder casting can be molded as easily in one case as in the other. While this is a very recent development, yet it promises such good results that we believe its quite general adoption is likely to be only a question of a short time.

While the boilers of locomotives have increased enormously in size, there has been little change in the actual design and

construction. Of course, the larger diameters have given occasion for the introduction of thicker sheets and for joints of increased efficiency. The old double-riveted lap joint, which had an efficiency of about 70 per cent., has been superseded almost universally by the butt joint, with an efficiency of from 80 to 90 per cent. Besides reducing the thickness of the shell sheet, the butt joint pulls centrally and removes the cause of grooving, which was so often found when boilers were provided with lap joints, no matter how strongly they might be riveted. This grooving was due to the eccentric pull of the two sheets on the joints, and has been largely responsible for shell ruptures. It is, moreover, difficult to see before trouble ensues, but it reduces the section of the plate by starting a fracture at the caulking edge of the inside lap. The butt joint which has generally been introduced has a wide inside and a narrow outside cover plate, but in some cases the diamond joint has been introduced, which makes a very stiff shell at the joint. Seams have been welded, not only at the ends but sometimes for the whole width of the sheet, but, as a rule, a cover plate is put on in addition to the weld, so as not to depend entirely upon the welded joint. There are different ways of making these welds, sometimes by means of direct flame or fire, sometimes with an electric arc, and sometimes with acetylene, the latter coming now into more general use as the apparatus is portable and does not require connection with any source of power to provide current.

Cast metals have almost entirely disappeared from boiler construction, whereas in former times, with low pressures, it was considered permissible to use cast-iron dome rings and dome caps, yet these are now invariably made of pressed steel. The complete dome is sometimes pressed out of a single sheet of metal.

The fire-box itself has been affected principally by the introduction of flexible staybolts. These are generally of two types, one with a spherical end encased in a cup screwed into the sheet, of which the Tate is perhaps the best illustration, and another one consists of a hinged bolt, of which the "Breakless" is the best known example. These were introduced to reduce the great number of breakages which some lines experience, particularly in the corners or ends of the fire-box. Some roads even go so far as to specify that all of the fire-box staybolts shall be of the flexible type, while the majority of roads are satisfied to put in

only 300 or 400 of such special bolts. These bolts add about 50 cents each to the cost of a locomotive, and the question has recently been raised as to whether they are really giving the immunity from breakage, which has been contended. The staybolt problem is rather a difficult question, inasmuch as if we make the bolt larger in diameter it will be stiffer and still less likely to stand transverse strain. With increasing pressures we cannot well make them thinner without reducing the spacing, and this is undesirable on account of the likelihood of the water space being choked up with mud. Then, staybolts are likely, if overheated, to let the crown sheet drop, and for this reason it is good practice to use button-headed bolts for the central rows of the crown sheet stays. The wide fire-boxes have long caused the practical disappearance of crown bars, so that there are practically either radial-stayed or Belpaire type of boilers in general construction at the present time. With the Belpaire the crown sheet is naturally level, but with the radial-stayed the high portion which would be first to be uncovered by low water is often protected by button-headed bolts. Some, however, think this a disadvantage and would prefer that a short section of the crown sheet should let go and relieve the pressure without pulling down the whole crown sheet. Records of locomotive boiler explosions, including dropped crown sheets, seem to indicate that less than 2 per cent. are due to deficient strength, and that practically all of the disasters are caused by low water, either through the negligence of the engineman or some difficulty with the water feeding or indicating devices.

In recent years the Jacobs-Schupert fire-box has been introduced as practically indestructible with even extraordinarily careless treatment in connection with fire and water. This boiler is composed of sections riveted to diaphragm sheets, so that no staybolt is used in the construction of the boiler, and some remarkable results of tests have indicated that it is very difficult, if not impossible, to cause a disaster by means of low water, even with a hot fire in the fire-box. Of course, this fire-box is more expensive to construct, and it is questionable whether the railroads would feel it necessary to pay this increased cost as an insurance against troubles of this kind.

The inside of the fire-box is occasionally provided with arches of various types; some of these rest on tubes and some on studs, some are made of solid bricks, and some are of hollow bricks

with openings through the front water leg to introduce air for combustion. Some recent tests recently made showed that there was little, if any, efficiency or economy afforded by means of jets of air brought in through the arch brick, and the greater expense of the brick and the difficulty of maintaining them would seem to give preference to a solid brick, particularly if there was no gain over the hollow tiles. However, these questions of combustion have been so much discussed and disputed, and as results of different tests are likely to show such a variety of results, it is doubtful whether the question of the value of the brick arch and its various forms for admitting hot air, etc., will ever be satisfactorily settled in any one way to the community at large. Most people agree that the brick arch has a very positive value in connection with smoke abatement and fuel economy; yet in some sections of the country where the flues need frequent rolling and beading it is almost impossible to maintain an arch for any length of time, and it often prevents the quick turning of a locomotive, as the man cannot get in the fire-box or remove the arch until it has become sufficiently cooled. These practical considerations are often much more important in a locomotive than the mere theoretical consideration of fuel economy, as the business of moving trains is of primary importance, and anything that increases the round-house work or detains the locomotive at a terminal is bound to give way to the urgencies of transportation.

While the burning of oil instead of coal in locomotives is of quite ancient origin, having been first introduced in Russia on the Grazi-Tsaritsin Railway, it was experimentally tried in this country, but for many years had nothing to recommend it, as compared with coal, on economical grounds. The discovery of the fine deposits of oil in Texas and California, however, where coal costs $6 or $7 a ton in the latter locality, gave an impetus to this feature that was an immense benefit to the railroads in many ways. The Southern Pacific and the Santa Fe have for the last fifteen years been making considerable use of crude oil in the southwest, and in later years the substitution of oil for coal has been carried to points as far east as the Rocky Mountains and generally throughout the state of Texas. The advantages, while being enormous, have been also accompanied by certain disadvantages which prevented this from being an ideal fuel.

It was found from actual tests that four barrels of oil were

practically equivalent to a ton of coal of the quality of Illinois bituminous, and, as there were usually six barrels of oil required to make up a ton weight, the ratio of heating value was as 3 is to 2. This is also in proportion to the number of British thermal units developed by burning a pound of these fuels, as mine run coal gives us in the neighborhood of 13,000 B.T.U. and fuel oil runs about 19,000 B.T.U.

Another incidental advantage that has been greatly appreciated in the last few years is that this oil can be put in without physical labor and makes it possible to keep steam up on a much larger engine than could be done with coal fired by hand. The unfailing source of steam is another advantage, as trains, even with the same tonnage, can make better time on heavy grades, as there is ample steam to keep the cylinders supplied at full pressure, no matter how hard the engine is being worked.

The universal method of generating steam from oil in a locomotive is by means of a special injector or atomizer, generally called a burner, in which the oil is sprayed by the steam pressure and is burned in this form of atomization. In order to maintain the combustion, the fire-box is lined part way up with fire brick, also having a floor of fire brick, which becomes quite hot and maintains the temperature high enough to ignite the oil. Formerly it was the custom to place the burner at the back end of the fire-box, spraying the oil ahead underneath a brick arch somewhat similar to the ordinary brick arches used with coal, but the latest practice is to place the burner at the front of the fire-box and spray the oil on a flash wall without using any arch whatever. This saves considerable expense, as the arch was very costly to maintain, sometimes falling down from the motion of the engine in two or three trips. It is also found by this location of the burner that the fire-box sheets give a longer life, as the intense heat of the oil flame causes a much more rapid deterioration than with coal, and especially was this found to be the case at the seams where two thicknesses of metal were exposed to the action of the fire. With the old method of using the arch, fire-boxes would often give only one-half or one-third the life of coal burners, and it was frequently necessary to renew a fire-box in about one year, very largely because it was impracticable to patch the fire-box on account of the double thickness of metal above mentioned. The new method of arranging the burner has

increased this life, and the practice of welding in pieces flush with the acetylene torch has also obviated the double thickness of an ordinary patch.

Even in spite of the extra cost of maintenance due to rapid fire-box deterioration, the use of oil was considered very desirable, as a dollar's worth of oil would often replace three or four dollars' worth of coal. Then, there was practically no fire thrown from the stacks, which is of great benefit in a dry country, and this feature alone led to the adoption recently of fuel oil by the New York Central and the Delaware and Hudson Railroads on their lines running through the Adirondack Forest Preserve of New York State. This matter was discussed very thoroughly before the Second District Public Service Commission, which finally decided that these roads should burn liquid fuel during the summer season in order to prevent the extensive forest losses which had resulted from fire thrown from locomotive stacks or dropped from ash pans.

The firing of oil is, of course, a specialty, as the supply of fuel to the burner must be regulated in connection with the engineer's operation of the throttle and the reverse lever. When the engine is standing, the supply of oil must be cut down to a very small quantity, such that it will just be sufficient to maintain steam, and as soon as the throttle is opened a larger supply of oil must be given, depending upon the amount of steam required by the cylinders. It is perfectly feasible to fire a locomotive with fuel oil without the emission of smoke, except that in periods of about every half hour it is necessary to work sand through the flues in order to clean out the soot that has accumulated, and, of course, this is accompanied for a moment by the emission of dense black smoke. When the engine is working properly, however, there is only a thin haze above the stack, although the least inattention on the part of the fireman will cause either the steam pressure to drop or the emission of large quantities of smoke.

Practically any locomotive that is suitable for burning coal can be converted into an oil burner, although there are some particular features to be borne in mind when an engine is being designed primarily for the use of liquid fuel. It is a very simple matter to construct an oil tank which shall fit into the coal space of the tender, and this is connected with hose or flexible pipes to the engine, passing through a heater so that the oil may be

rendered still more fluid, if necessary. Steam jets can be used to warm the oil in the tank when necessary, and there is generally a safety connection which, in case of the separation of the engine and tender, closes the oil valve, preventing it from running over the track. The California oils are ordinarily non-inflammable at the usual temperatures, and there is little or no danger attending their use. Some of the Texas oils, however, are more readily inflammable, and it is necessary to exercise extreme caution going about a tank with an open light. Asphyxiation is also liable to occur when men go inside of tanks to clean them out, particularly with the Texas oils, and these tanks should always be steamed out thoroughly before anyone enters to do any work. The actual cost of converting a coal-burning locomotive into an oil-burner varies from $500 to $800, dependent upon the size of the engine; but, of course, the incidental expenses, such as the maintenance of storage and delivery tanks, tank cars for transporting the oil and pumping it into the storage stations, are all part of the general cost of introducing such a system, and will oftentimes amount to a great deal more than the actual equipment of the locomotives.

The large locomotive, with its heavy draught of steam upon the boiler, necessitating the combustion of great quantities of coal, has brought about a number of appliances for diminishing the work of the fireman so that he can confine his efforts to actually delivering the coal into the fire-box; everything that could save a step or an extra motion of his hands or his back having in some cases been introduced, so that he could give the maximum output for the generation of steam. The old-fashioned fire door, which was swung with a chain and which was supposed to be opened and closed with each shovelful of coal, has been found troublesome in large engines, and, therefore, pneumatic fire doors have been introduced. These are arranged so that when the fireman has a shovelful of coal ready to throw into the door a pressure of the foot upon a treadle in the floor of the cab admits air to a small cylinder which slides each half of the fire door in opposite directions, thus opening the door for the admission of coal without any further action upon his part. As soon as the foot is removed from the treadle the door closes. This, besides relieving the fireman of the extra motion and effort, insures more perfect combustion, as the door is naturally closed after each shovelful

of coal. Wide fire-boxes are in some cases provided with two fire doors, and it is not always as convenient for the fireman to use one door as the other, especially in connection with operating the fire door by hand, but these pneumatic devices prevent much of this trouble and assist very materially in the operation of firing.

The same principle has been applied to shaking the grates. While with short fire-boxes this was a comparatively easy operation, with the present length of furnace, which is in the neighborhood of eight and ten feet, and the width, which in some cases is eight or nine feet, it is not only necessary to shake the grates in sections, but it becomes quite difficult actually to do this work. Pneumatic or steam grate shakers have therefore been introduced in which a small lever operates the valve of a cylinder, which in turn gives the necessary travel to the grate arms in order to thoroughly shake up the coal bed to free it of clinkers and ashes.

Still another device has been introduced on the tenders in order to prevent the many steps needed when the coal has been partially exhausted and the fireman must go to the back of the tender coal space to shovel up the fuel. This mechanism consists principally of a steam cylinder placed inside the tank in which a piston is operated connecting to a false or inside bottom of the coal space, and when pressure is admitted to the cylinder the piston pushes up the back end of this false bottom, which is hinged to the front, allowing the coal to slide forward so it will be close to the gate and not require the extra steps and movement necessary in the ordinary type of tender.

While these different items seem small in themselves, yet, when they are all introduced together on the same engine, it is remarkable how much they save the fireman from a labor that can be performed mechanically as well as manually, and I have been impressed with this upon large locomotives where firemen have been enabled to put in very much greater amounts of coal than would ordinarily be expected.

The greatest improvement, however, has been in the development of the automatic stoker, which not only combines the several features above mentioned, but actually brings the coal from the tender and puts it in the fire-box. The first type developed was probably that invented by Mr. Kincaid, a former engineer on the

Chesapeake and Ohio Railway. This was really a steam shovel and placed back of the fire door, coal being thrown in the hopper from the tender by the fireman with a shovel, the apparatus, however, delivering the coal into the fire-box. This represented very largely the ordinary method of firing, as the fuel was thrown on top of the fire in the furnace and regulated the supply to be put in in large or small quantities and at regular intervals, so that the smoke production could be better controlled. There were means for distributing the coal to different portions of the box, and I have seen engines come in from a run with as level a fire as could be desired, the firing having been done entirely with this device.

There was, however, no arrangement to take the coal from the tender to the stoker, and we think this is very important. Quite a number of stokers have recently been developed, in some of which coal is thrown in as in the Kincaid by a steam piston, the valve of which is moved by a small engine, the speed of which can be regulated, and in others the fuel is blown in by steam jets. There are also methods of introducing the coal below the grate, such as the Crawford and the Barnum stokers. In the first of these the coal is pushed forward under the grate by means of pistons through tubes and slowly pushes up and flows up over the grate. In the latter stoker this is done by the operation of worms similar to those used in flour mills. The coal in both cases is carried from the tender by means of worms or a conveyor. As the rate of combustion in a modern locomotive can be forced up to 200 pounds of coal per square foot of grate surface per hour, it is evident that the problem is not only to get sufficient coal into the fire-box, but also to get it in such condition that it will be ignited and burn at the desired rate. Naturally an underfeed device must be slower of ignition, but this takes care of itself, as the raw coal piles up over the slots and rolls over in the bright portions of the fire where the flame can reach to every surface of the piece and readily ignite it.

Claims for smoke reduction and fuel economy have been made, but really the principal point of the stoker is that it enables us to obtain more work out of the engine than would be possible with a human fireman. While the locomotive has increased in size and weight, its output in horsepower is generally very much below the increase in size, and, as previously stated, a very large

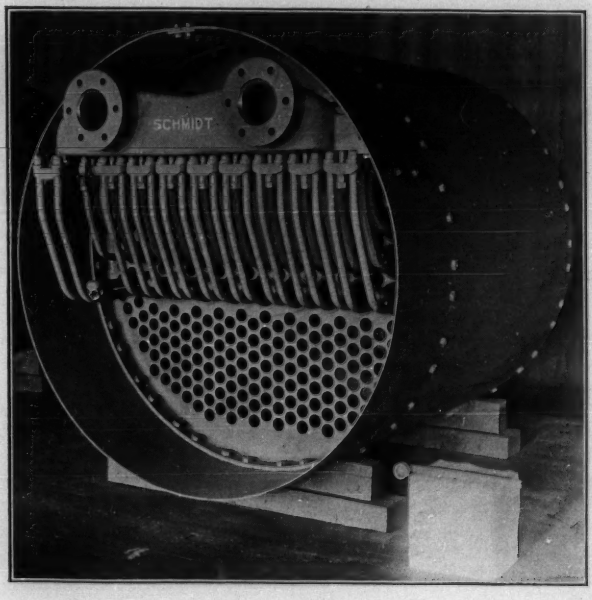
engine will often develop no more actual horsepower than a much smaller one, although its tractive force will be very much greater. The limit seems to be the capabilities of the fireman, and, if this can be increased by mechanical means, not only will we be able to get more power from our engines, but the fireman's work, being less laborious, will be more attractive, so that higher-grade men can be obtained who will be able to use their heads and not depend entirely upon muscle and brawn for generation of steam.

Mention has been made above of the introduction of various superheaters and reheaters for use in connection with locomotive boilers in order to increase the output of the boiler and, incidentally, the fireman. The superheater has developed on three or four different lines—viz., one, in which a number of steam pipes are placed inside of the fire or smoke tubes, allowing the steam to be further heated by direct contact with the gases of combustion after it has passed from the boiler; another one, in which there has been a combustion chamber or pocket formed in the boiler itself, into which a receptacle has either been built or subsequently placed, permitting the steam to come in direct contact with the flue gases; and, third, in which a series of pipes are placed in the smoke-box of the engine to make use of the gases after having been discharged from the flues, the steam from the boiler passing through these pipes on its way to the cylinder. It is manifestly obvious that this latter method, using only the heat remaining in the gases after having been passed through the flues, will not receive as high a temperature as that which extends through the fire tubes toward the fire-box, but, at the same time, there are other advantages, several of which are that the heating surface of the boiler is not necessarily diminished by introducing this type of superheater, and that it can be applied to an existing locomotive, in many cases, without any material changes in the boiler. While the superheat obtained from the smoke-box type will average only from 30° to 50° Fahrenheit, yet the fact that the moisture in the steam is thoroughly dried out and that cylinder condensation is largely reduced, has made a very good economical showing for this type of superheater. Fig. 8 shows the Schmidt fire-tube and Fig. 9 the Vauclain smoke-box superheater.

With the fire-tube and chamber type of superheaters it is possible to get as much as 150° to 200° superheat, and some recent tests have been reported in which the temperature ran consider-

ably higher than these figures. These superheaters, being exposed to the more or less direct action of the fire, are more liable to burn out than those in the smoke-box and are, also, as a rule, more expensive to apply and maintain.

FIG. 8.



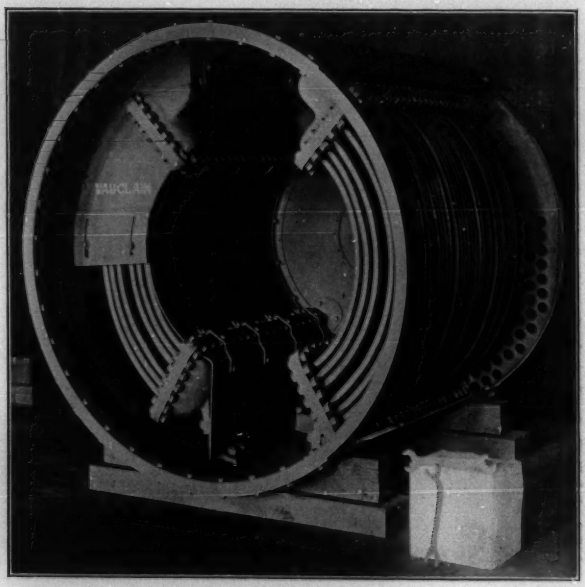
Schmidt superheater.

There are many varieties of fire-tube superheaters, and some of them are easy of access for removal of the superheating pipes and some are difficult. The tendency in recent designs, however, has been to develop a superheater in which the elements can readily be removed without necessitating the removal of many other parts, thereby delaying the engine in the round-house and keeping it out of service. This is an important factor in railroad

operation, as no matter how much economy can be obtained from any device, if it were to cause much loss of time from actual service by requiring repeated and extensive repairs, it would not receive favorable consideration.

The action of superheat upon the work of a locomotive gives,

FIG. 9.



Vauclain superheater.

as is well known, this advantage by increasing the volume of the steam delivered to the cylinders and, at the same time, the superheating prevents in a great measure cylinder condensation, as temperature of the steam must be lowered by the amount at least of its superheat by the processes of expansion before it can be condensed in the cylinders. The economy of superheat locomotives in coal consumption varies from 10 to 20 per cent., and

cases have been recorded where as high as 30 per cent. economy has been obtained. We think, however, that under ordinary service from 15 to 25 per cent. may be expected. This has an advantage in addition to the saving in fuel consumption, in that it also saves the labors of the fireman and enables him to give a greater output in horsepower for the same amount of physical energy expended.

It has been claimed that the increased volume due to the superheating could be utilized by operating at lower boiler pressures and thus reducing the amount of repairs on boilers of locomotives, which has become very onerous under conditions existing in modern locomotive practice; so that, even if there were no especial fuel advantage obtained, there would be a saving in boiler repairs. It must be borne in mind, however, that the loss in pressure in passing through superheaters is sometimes quite considerable, amounting to possibly 20, 30, or even 40 pounds per square inch drop from the boiler to the cylinders, and in order to make up for this and to maintain the proper working pressure in the cylinders it is necessary to operate the boiler at a considerably higher pressure than it is desired to supply to the cylinders. In Germany it is quite a common practice to have two gauges, one indicating the pressure in the cylinders and the other in the boiler, and the latter is carried so as to maintain the desired pressure in the cylinders. In this country 170 pounds is a rather favored pressure for superheater engines, and, of course, the cylinders are proportioned to give the proper tractive force with this pressure, thereby making the reciprocating parts larger than would be the case with high-pressure steam. Boilers are generally, however, designed capable of carrying 200 pounds per square inch, so that at any time the safety valves can be adjusted to allow for the drop in pressure passing through the superheater. Of course, it means a certain amount of lost work, and in some cases superheaters have been arranged in which the steam passes through a single loop in the fire tube instead of the double loop, as ordinarily used. This would naturally reduce the loss about 75 per cent., and this means a great advantage in the operation of the engine.

The action of the fire on these inside tubes when steam is not passing is sometimes prevented from overheating them by means of an automatic damper in the smoke-box, which closes when

no steam is passing through the superheater, thereby preventing the overheating of these pipes.

With superheaters of the chamber type it has been found that the large volume of steam outside of the throttle at times prevents a prompt response of the locomotive to the engineer's movement of the throttle lever; in starting, for instance, this chamber must fill up with steam before the pressure will accumulate in the cylinders sufficiently to move the train, and upon closing the throttle the expansion of this steam causes the engine to run farther than would otherwise be the case. It has been suggested that the throttle valve be placed outside of the superheater in order to overcome this difficulty, but this, of course, has been open to the objection that when standing the superheater might fill up with water, endangering the cylinders when the engine is started.

The whole superheater question is, in a measure, in its infancy, and, while there are a great number in use, yet we do not feel that there has been a sufficient amount of experience with them in this country so that all the benefits and difficulties can be as yet definitely determined. Anything that will increase the output of a locomotive will be looked upon with favor, unless, as stated above, there may be delays owing to necessary repairs that may more than make up for the efficiency of the engine when in operation. Of course, it must always be remembered that such devices have their benefit only when the engine is actually working steam, as on an up grade, or working on a level. During times of running down hill, standing at stations or terminals, remaining on side tracks or in the round-house, these advantages are absolutely unavailable.

From a number of tests made at the Purdue University by Professor Goss, in which the running of the engine was intermittent, they found that the steam consumption per unit of work delivered was increased, due, no doubt, to the cooling of the cylinders and the connected parts, and that this loss increased with higher steam pressures. When the programme of operations was intermittent with equal periods of running, the loss was found to be from 5 to 10 per cent. more than that under constant running, and when the reduction by stack losses and periods of idleness were also considered, the results were about 20 per cent. less favorable than during constant operation. This, however, does not consider the absolute uselessness of this or any other device

when the engine is running down hill or standing, and the additional expense for its original application to a locomotive means a constant interest charge. These things should all be considered in making any final estimates as to the value of this or any other economical device, but they are too often overlooked in the enthusiasm of those who are anxious to make a saving in coal consumption.

Reheaters have much the same function as superheaters, except that this term is applied to such devices as impart heat to the steam in its passage from the high-pressure to the low-pressure cylinders. The low-pressure cylinder, naturally, is that which produces the greatest amount of condensation, and, if we are able to reheat the steam after it has exhausted from the high-pressure cylinder, we will save considerable condensation in the low-pressure cylinder. Reheaters are seldom used alone, but are generally used in connection with superheaters which heat the steam before passing into the high-pressure cylinder. The exact amount of saving to be accomplished by a reheater is not definitely known, but it is probably somewhere in the neighborhood of 5 to 10 per cent.

Reheaters are generally either of the box type or of the smoke-box type, and in design they resemble an ordinary superheater of these two varieties.

Feed-water heaters are of a similar nature and construction, although they are generally made of the box type. The flexible boiler makes a very convenient use of the front section by placing therein a reheater, and even in some cases with rigid boilers where the length would be too great for the application of tubes satisfactorily a feed-water heater is placed in the front end and the water from the injectors flows through this feed-water heater, which is warmed by the gases of combustion after passing through the flues.

It has been customary, in many cases, to run with this section full of water, the water then passing from the top to the boiler, being fed in near the bottom of the feed-water heater. The electrolytic action, however, in many cases causes trouble and pitting of the flues and sheets, although the boiler itself is not affected in a similar way. This seems to be worse in good water districts than where scaly water is used, and it is thought to be due to the oxygen carried in with the water. The latest practice

has been to connect this with the steam space directly and run it at the same level as the water in the boiler, making this really an extension of the boiler, and, while it seems somewhat strange that such should be the case, the economy, which is from 5 to 10 per cent., seems to be practically the same whether this acts entirely as a heater or whether it is connected up to form an extension of the boiler.

ELECTRIC PROPULSION.

In the last ten years the wonderful advancement made by electricity in all lines of work has led some to believe that the days of the steam locomotive are actually numbered and that it would soon become a thing of the past. This belief has been expressed by some men of high standing in political affairs, if not in mechanical, and the great successes attending the application of electricity to street-car lines, suburban transportation, elevated and subway roads have rather brought about a popular opinion harmonizing with the above-mentioned assertion.

The difference between the operation of a street-car system, suburban system, elevated or subway railroad is so entirely different from the operation of the average steam railway that there is really little actual comparison between the two. Estimates have been made upon the cost of operation of a steam line, based upon the results found when the elevated railway lines in New York City were electrified, by comparing the new results with those of the old steam operation, and it was only a few years ago that some electrical engineers of considerable reputation advanced the theory that if all the steam railways in the country were to be electrified a saving in the cost of operation would be made which, while not quite equal to that claimed by Mr. Brandeis, would be effected by adopting economies, yet would be well worth considering as means for economical operation.

No one can deny for a moment the great advantage to city and suburban life of the trolley car, and it is this, probably more than anything else, that has given our cities an outlet for their increasing population and made suburban life a happiness instead of a drudgery; but even this has not been altogether without financial disappointment to the electric railway companies, as only a few years back many of them were being sold under foreclosure and only really made money when operating upon a new basis of

cost, which had the result of very materially scaling down their fixed charges.

When we consider the application of electricity to the New York Central Terminal tracks in the city of New York, it is often asserted that this substantiates the theory of the devotees of electric propulsion, and this has been made such capital of by electrical engineers in order to enforce their pet schemes, which have been, no doubt, largely developed by over-enthusiasm in their particular line of work. As a matter of fact, the profit of operating the New York Central Terminal line by electricity over the steam lines is not large, and the capital expenditures have been something enormous. It was stated several years ago by the vice-president in charge of electrification that the consequential costs were about four times the actual costs of electrification, by which he meant the arrangement of depots, tracks, terminals, round-houses, and other facilities which would necessarily enter into the electrification. The fact that there is a margin of profit was shown very clearly in a paper presented to the American Society of Civil Engineers by the official mentioned above, an analysis of which showed that if the actual amount of traffic or the load factor had been less regular there would have been an increased expense instead of an economy. To make this somewhat clearer, we would state that if the power requirements had been so irregular that the facilities of the power-house would need to be doubled to carry the movement over the maximum peaks there would actually have been an extra expense, but, on account of the uniformity of movement, the power-house equipment could be so adjusted that the interest on investment was not so great as to overcome the economy effected in the actual movement of the trains.

On the other hand, it has been but a few months since the New York, New Haven and Hartford Railroad claimed an increased cost of operation, due to electrification, when this subject was considered for the application of similar conditions to the Boston territory, and, at the best, it would seldom, if ever, be claimed that the economy resulting from electric operation will ordinarily be so great as to make it an attractive financial proposition for the substitution of electricity for steam. There are other conditions, of course, besides the financial part of the problem, such as existed in the tunnel under Park Avenue in New

York City, where steam operation was almost intolerable to patrons of the road, not only from the liability to accidents, but from the partial suffocation which everyone experienced in going through the tunnel in hot weather. The question of relieving the city of the smoke of the locomotives was also an important consideration, and it was these features and *not* the prospect of financial improvement that forced the electrification upon these roads, and we believe that we may well say "forced," as they certainly would never have gone into this project had they not been driven into it by the residents of New York City and the commuters who daily passed through the inferno of the Park Avenue Tunnel.

The consequential damages referred to above can sometimes be reduced or made into an actual asset by utilizing the space which would not be available under conditions of steam operation. This is illustrated by the New York Central construction which is now being completed in New York City. The large amount of open space required for the escaping of the gases and steam from the locomotive smokestack can, in the case of electric operation, be reduced to a very small quantity, and the overhead space so vacated by steam and smoke can be utilized for office buildings and other purposes. Of course, this depends largely upon the locality, and there are comparatively few places in the world where this would be as remunerative as in New York City. It is a phase of electrification, however, that should be given due weight when considering the financial returns on any scheme of this kind.

On the other hand, we must consider what actually happens in the way of transportation density and uniformity on many of the railroads in this country, and perhaps we should say on nearly all of them, outside of a few in the most populous districts. It has been claimed that the one requirement for successful financial electric operation was density of traffic, but we believe that uniformity is just as important as density. For instance, let us compare a road like the New York, New Haven and Hartford Railroad or the Pennsylvania's Atlantic City line. Here the passenger travel is great at all times of the year, and is quite uniform during the day and night, so that frequent train service is required at nearly all hours. In this case we have not only density but uniformity, and, as stated above, it is this item that gives us the saving in the electrical operation to the New York Central's Terminal System. The same is true of the New York

Elevated, which runs trains very frequently at all hours of the day and night, maintaining a high load factor, which, while there are peaks, to be sure, yet these peaks are not so far above the average movement as to require an excessive expenditure for installation in the power-house.

From this let us go to the other extreme and consider a line in the West where there is very little local traffic, except that on one or two nights in a week a heavy stock business exists to bring cattle to the following day's market. This business is onerous and exacts and requires high speed and delivery at the expected time without fail; otherwise consequential damages may be assessed against the carrying road. It is not uncommon for this division, which may see two or three trains a day ordinarily, to have twelve or fifteen heavy stock trains pass through it in the course of a few hours at some one or more times during the week. These trains are usually sent in fleets in order to insure better dispatching and also to enable them to arrive in suitable time for the next day's market. The amount of power required on this division at this particular time would be extremely high. If we consider such trains (and they are run at high speeds requiring about 2,000 horsepower for their operation) and that fifteen are handled, we see at once that each division power-house must be sufficient to give at least 30,000 horsepower output. The rest of the week the output would probably not be over 3,000 or 4,000 horsepower at any one time, so that a large amount of machinery must be installed in the power-house to carry this exceptional peak load, and this machinery is non-remunerative for the other six days a week and represents idle investment. This must be repeated at every division power-house which is used to provide power for such a movement, and shows at once the futility of arguing that electrification would be applicable to all roads. The steam locomotives can be bunched, grouped, and transferred from one division to another and make a particularly elastic medium of power transmission, as the next day the locomotives can simply be placed upon another division where their services will be needed; moreover, the cost of a horsepower represented by steam locomotives is approximately $15 each, whereas a modern power-house with the transmission lines will cost fully $100 per horsepower, to say nothing of the fact that electric locomotives are nearly double the price of steam locomotives.

These conditions are brought to your attention, not with the idea of belittling by any means the use of electricity for transportation purposes, or of trying to prevent extensions in that line, but are simply presented so that these matters may be so clearly understood that the enthusiasm of some electrical experts may not be permitted to get the best of sound judgment, which will eventually react and injure the cause more than it will help. On the other hand, we would not be surprised at any time to learn that the Pennsylvania Railroad, for instance, would electrify its entire system between New York and Washington. The present New York Terminal is operated entirely by electric locomotives; the subject is being now studied in regard to Philadelphia; the tunnels at Baltimore will certainly soon require heroic treatment; and, in order to prevent the objectionable smoke in the capital of our country, electric traction would be considered a great advantage. These four links in a line 250 miles long, and the density and uniformity of traffic which passes over these divisions, make this quite an attractive subject for electrification, but there can be no comparison between this piece of track and that above described, and which is found in most of our western States.

We have refrained from going into figures on this subject, as statistics are difficult to properly interpret, unless they are given in great detail and carefully analyzed, and the different factors entering into the subject are so varied that it requires a great deal of study to actually determine the line between gain and loss. Each individual case must be studied under its own conditions, and only in a general way can we draw deductions from one existing line with which to prognosticate safely the results of some other line. There is no question but that electric traction will increase, but we believe that steam traction will increase still more rapidly, and that the steam locomotive will not be relegated to the museum or the scrap pile during the life of any one present at this meeting.

There are three different ways in which electric locomotives can be operated: first, by collecting the current as the locomotive moves from either a trolley wire or a third rail; second, by means of storage batteries carried on the engine or tender; third, by means of internal combustion or other motors generating electricity as required which actuate motors geared to the axles. The

first method has certain advantages not enjoyed by the others, and is the one generally employed for handling heavy trains through long distances. The great advantage which results from this arrangement is that the full output of the power-house is available at the motors and the capability of doing work is limited only by the characteristics of the motors installed upon the engine. It is possible with such a combination to obtain much greater tractive forces with high speeds than can ever be hoped for with a steam locomotive, because the latter is dependent upon the capacity of its boiler and fireman, whereas the electric locomotive can receive its power from a plant which will deliver many more horsepower than could possibly be obtained from a locomotive boiler. It is this phase of the question which has been urged so largely in the endeavor to place electric locomotives on heavy grades and mountainous sections, but, outside of some special pieces of track where tunnels make the operation of steam locomotives objectionable, there has been little done in this country along this line, and, although such plans have been investigated, they have not ordinarily been found to be financially attractive. There is no question but what there are great possibilities in this line, provided that the costs are not out of proportion to the benefits developed. The motors, of course, have certain limits, principally governed by their ease of disseminating heat, and it is the heat limit that prevents more power being put through any given motor. There have been cases in the West where even water power, with its generally attractive features, has not been considered as a satisfactory financial proposition; where the cost not only of producing but of transmitting the electric current from the water power to the railroad was found to be too great a financial burden to expect an equivalent return.

For comparatively short lines with dense and uniform traffic, however, there is probably no other method which is likely to be considered, the choice lying between the third rail and the overhead trolley suspension. Both systems have their advantages and disadvantages, but either can be operated satisfactorily, as demonstrated by the locomotives used on the New Haven Road, which, while on the direct current territory of the New York Central, collect from a third rail, and when on the alternating current sections of the New Haven collect from an overhead wire. The motors in this case are single-phase and can be used either

on direct or alternating installations. In the latter case the current is transmitted and used at a high voltage, namely, 11,000, while in the direct current the ordinary voltage is 660. It is this difference in voltage that makes it feasible to use third rails with low voltage, which would be considered unwise with the voltages used on the New Haven overhead line. Even at certain points the low voltage direct current must have overhead connections, as at complicated switches and crossings where a continuous third rail is not practicable, but that both systems can be operated satisfactorily is amply demonstrated not only by the trolley car service with its suburban connections, but by the several steam lines which have divisions operated electrically.

There are certain places, however, where it seems impracticable to use satisfactorily either the overhead trolley or the third rail, and these are in freight and classification yards where much shifting is necessary and a great number of switches are encountered. The necessity for men moving on foot over such a yard to do their work in connection with the makeup of trains renders the third rail a very serious obstacle, and the presence on top of box cars of brakemen giving signals, etc., renders an overhead wire dangerous and unattractive. For such a condition, either a steam locomotive burning anthracite fuel or with some smoke-consuming device that is effective can be used, or a locomotive operated with a storage battery, which is, perhaps, the most attractive proposition. These batteries can be carried in a separate car or tender and can be recharged and simply picked up by the locomotive, discarding its discharged battery car when necessary. Of course, the expense of such a locomotive is high, and it is possible that some special batteries like the new Edison quick-discharge and recharge battery would alone be acceptable, but the expense, of course, would not be as great as the installation of third rails and overhead wires, and the locomotive has the advantage that it can move on ordinary track, pass into and out of private yards and buildings without any restrictions, and can simply replenish its current when necessary as a steam locomotive would take on coal and water. On account of the great cost of these locomotives, however, which is principally involved in the storage battery, it is not likely that such a system would be developed to any great length of line, but for terminal work and switching around a number of spurs and individual properties it seems like a very attractive proposition.

The internal combustion motor generating its own current has been made use of in a number of isolated cases, and for branch service and where the service is light and the trains few it answers the purpose admirably. This, however, is also quite an expensive machine, as we must have the power generated converted into electricity and back again by the motors into power, which makes an elaborate system of machinery, and, while it answers the purpose well for branch service, it would not be satisfactory for hauling heavy trains in main line work. The cost of operation of such motors is comparatively low, but the principal saving is in reducing the number of men in the crew. A single car can be operated with two men, whereas the least number that could be run with a steam locomotive and passenger cars would be four men. The uncertain cost of gasolene is also a factor in this method of operation, which is not entirely satisfactory, and when it comes to taking care of such a machine it is certain the car shed will not be a suitable place for doing this work, nor will the roundhouse be appropriate for the passenger portion of the vehicle. We therefore believe it safe to say that for heavy main line work either the third-rail or the trolley system will be found most acceptable, and that the second and third systems above described will be found useful adjuncts for certain parts of a railroad system, but that they cannot be seriously considered for heavy through traffic.

The type of electric locomotive which collects current as it moves, whether by trolley or by third rail, has individual characteristics considerably different from the steam locomotive. Several general arrangements are in use which might be divided ordinarily into three different types: first, that in which the motors are mounted directly on the driving axles of the locomotive, although this does not mean rigid connection, as they are generally arranged to turn the driving wheels through a flexible connection; second, that in which the motors drive the axles through the medium of spur gearing; and, third, that in which the wheels are driven through connecting rods. In the early days of the development of electric locomotives the first arrangement was considered the most desirable, as the centre of gravity was brought quite low and there was an absence of connecting and transmitting machinery. For many years the increasing heighth of centre of gravity of locomotives has been a bugbear to railroad men, and, when the very low centre of gravity produced by the first arrange-

ment of locomotive was proposed, it was considered that this would be practically ideal. One or two disastrous wrecks, however, led to a more careful study of this question, and one railroad made an elaborate series of tests with different types of steam and electric locomotives, both on straight line and curved, to determine what arrangement of wheels, etc., gave the least strains upon the track.

While the high centre of gravity is more dangerous by overturning the locomotive at excessive rates of speed, yet there is no question but what the low centre of gravity puts more stress upon the outer rail of the curve and its tie connections. This may be illustrated by the accompanying diagram, in which it will be seen that while the centrifugal force is the same for locomotives either with high or low centre of gravity with the weight, speed, and radius of curvature the same, yet the high centre of gravity throws an increased weight upon the outer rail, thus forcing it more tightly to the ties and reducing the shearing effect of the horizontal centrifugal force. The later electric locomotives which have been built for the Pennsylvania Railroad are operated by a single motor connected to the wheels by means of an inclined connecting rod. This gives the advantage of concentrating the power into one motor, which is generally more efficient, and also raising the centre of gravity more to the conditions of a steam locomotive. The geared locomotive raises the centre of gravity to a position between the connecting rod and the engine in the gearless type, but does not concentrate the effort into a single motor.

A technical discussion of the details and characteristics of these different types would be out of place in such an article, and all of them are giving very satisfactory results in service, but the principal points of interest have been referred to so that in a general way some idea could be had of the line of thought leading to these three varieties.

As to the question between direct and alternating current, each has its advocates and each has some advantages not possessed by the other. Alternating current motors, when of the single-phase type, can be so constructed that they will operate on either direct or alternating current, although a motor that is built for operation on only one, will be more efficient and lighter than a locomotive built to operate on both circuits. One of the principal reasons

for increase in weight in the combination locomotive is due to the fact that it must be provided with both resistance grids for the D. C. current and auto-transformers for the alternating current. With the direct current, the speed regulation is arranged by using the series or parallel operation in connection with reducing the voltage by passing it through resistance coils or grids. This is wasteful and is only intended to be used in starting and under certain conditions of slow speed. The alternating current varies the voltage by means of taps taken off from different parts of the transformer coil, and is free from the wasteful resistance of the direct current means of regulation. Both types can be coupled up to provide multiple unit control, so that one, two, or more sections can be used in accordance with the needs of the train to be hauled. The leading unit only need be occupied by the motorman and assistant. With such a combination there is almost no limit to the amount of power which can be developed, as each unit is limited only by the heat characteristics of its motors. Regardless of the great power which can be supplied by such units, however, the service so far performed in this country is nearly all passenger, and little freight work is being done by electric locomotives on trunk lines. Of course, this statement is not strictly true if we consider such cases as the Baltimore tunnels of the Baltimore and Ohio, the tunnel under the river at Detroit, and the Sierra Nevada tunnel of the Great Northern, and other points where steam operation would be particularly objectionable; but, outside of a few special cases such as above mentioned, the electric service is confined almost exclusively to passenger transportation.

Formation of Petroleum. C. ENGLER. (*Petroleum*, vii, 399.)—This is an extension of the author's theory that petroleum is produced from organic remains. The residual fatty substances (including waxes, resins, etc.) left after the decomposition or putrefaction of the protein, cellulose, etc., are considered to be gradually converted into anabitumen (soluble in benzene, carbon bisulphide, and other organic solvents), which undergoes further changes into other forms of bitumen; *e. g.*, polybitumen, katabitumen, ecgonobitumen or crude petroleum, oxybitumen or asphaltum. The results of his recent work in conjunction with Routala and Halmai are then adduced to explain the production of the different types of natural petroleum from a common source.

Crystolon (silicon carbide).—Amorphous silicon carbide, in the form of "carborundum fire sand," makes a good lining for electric-resistance furnaces, and is also useful in fuel-fired furnaces as bricks, or lining, or even as a "wash" applied to the firebrick walls. It is also used for repairs and as a firebrick cement. It becomes somewhat plastic at a very high temperature, and can be used without a binder. At still higher temperatures, in a reducing atmosphere, it is converted into crystalline silicon carbide. The heat conductivity of amorphous silicon carbide is higher than that of firebrick. Crystalline silicon carbide, or crystolon, is still more refractory than the amorphous form; it has a higher heat conductivity even than alundum and a smaller coefficient of expansion than silica. For making shaped articles of crystolon, powdered silicon carbide may be molded with the aid of a temporary binder, such as glue or dextrine, and then heated in an electric furnace to the temperature of formation of silicon carbide, whereupon crystallization or re-crystallization of the carbide takes place and a strong article is obtained. Bricks made in this manner serve well as a roof for electric furnaces. Owing to their high heat conductivity these bricks must be backed with a course of firebrick or other heat-insulating material; and the electrodes should just fit the openings in the firebrick, but have a clearance in passing through the crystolon, as this is a conductor at high temperatures. Crystolon articles made with a small amount of clay binder, however, act as insulators for most practical purposes even at high temperatures. In some experiments in an electric furnace with a crystolon brick roof it was possible to destroy the magnesite lining of the furnace and to melt the firebrick covering the crystolon, without damaging the latter.

Electrically calcined magnesia.—Magnesia calcined at a very high temperature in an electrical-resistance furnace is practically free from the defect of cracking, when heated to high temperatures, that is shown by ordinary calcined magnesia. The electrically calcined magnesia absorbs carbon dioxide so slowly that it is practically negligible.

Fused lime.—Lime fused in an electric furnace is a much better heat conductor than ordinary quicklime, and withstands sudden cooling after heating. It is much less readily hydrated.

New Electric Bicycle Lamp. ANON. (*Amer. Mach.*, xxxvi, 16, 615.)—A new electric bicycle lamp has been introduced in Amsterdam, the electricity for which is generated by the operation of the bicycle. A small wheel attached to the shaft of the dynamo rests on the front or rear wheel of the bicycle, making several revolutions for each one made by the larger wheel. When the lamp is not needed, this small wheel is released by a lever from the bicycle wheel. At a speed of 15 kilometres (9.32 miles) per hour a very powerful light is obtained, but a lower speed gives sufficient light.

A GENERAL FORMULA FOR THE TORSIONAL DEFLECTION OF SHAFTS.*

BY

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Introductory.—In a previous article,[1] by considering the internal work of deformation, the writer has derived a general formula for the shearing deflection of beams of arbitrary cross-section, either variable or constant. By the same method, a new and simplified proof of the Fraenkel formula for flexural deflection was also obtained in this article, and it was further shown that all the ordinary formulas for either flexural or shearing deflection are special cases of one or other of the above. Practical application of these formulas was then made to the calculation of the deflection of a planer rail for which both the cross-sectional area and moment of inertia were variable.

The object of the present article is to complete this work on deflection by deriving a general formula for torsional deflection. The usual analysis of torsional deflection, as given by St. Venant, Bach, and others, involves a more extensive knowledge of higher mathematics than possessed by the average engineer. The derivation here given, however, is very brief, and involves no mathematical principle more difficult than elementary integration.

Internal Work of Torsion.—In deriving the general formula for torsional deflection, the following notation will be used.

Let W = internal work of deformation under torsional strain,
G = modulus of shear (or modulus of rigidity),
ρ = unit angular, or shearing, deformation,
T = external torque or twisting moment applied to the ends of the shaft,
q = unit shearing stress due to torque T,
q' = unit shearing stress due to unit torque,
A = area of cross section of shaft.

* Communicated by the Author.

[1] JOURNAL FRANKLIN INSTITUTE, April, 1911.

Then if dV denotes the volume of an element of the shaft, the internal work of deformation on this element is

$$dW = \frac{1}{2} q\phi \, dV,$$

or, since $dV = dA.dz$, where dz denotes an element of length of the shaft, and also since, by Hooke's law, $\frac{q}{\phi} = G$, this may be written

$$dW = \frac{q^2 dA \, dz}{2G}.$$

Consequently the total internal work of deformation is

$$W = \frac{1}{2G} \int_0^l \int_0^A q^2 dA \, dz.$$

For a prismatic shaft—that is, one of constant cross section—this expression may be integrated with respect to z, and thereby simplifies into

$$W = \frac{l}{2G} \int_0^A q^2 dA.$$

It should be noted that this is a surface integral, and hence when rectangular coördinates are used it becomes a double integral, as shown in the applications which follow.

Theorem.—Let ϑ_1 denote the angle of twist, or torsional deflection, produced in a prismatic shaft by a unit torque, say one foot pound. Then the angle of twist ϑ actually produced by any given torque T will be $\vartheta = T\vartheta_1$. Now let W denote the work of deformation produced by a torque $T + K$. Then if K is increased by an amount dK, the angular deflection is increased by an amount $\vartheta_1 \, dK$, and consequently the total work W is increased by an amount dW such that

$$dW = (T + K)\vartheta_1 dK.$$

In this expression the work done by dK itself is neglected, since it is infinitesimal in comparison with the work done by $T + K$. Hence

$$\frac{dW}{dK}=(T+K)\vartheta_1,$$

and therefore, since $\vartheta = T\vartheta_1$, the angular deflection ϑ produced by the torque T is given by the expression

$$\vartheta=\left[\frac{dW}{dK}\right]_{K=0}.$$

This result is analogous to Castigliano's theorem on the deflection of beams.

Derivation of Formula.—Let q_0 denote the total unit stress due to the combined torque $T+K$. Then

$$q_0=q+Kq^1$$

where a and b denote the semi-axes of the ellipse. Consequently the expression for the work of deformation due to $T+K$ becomes

$$W=\frac{l}{2G}\int_0^A (q+Kq^1)^2dA.$$

By the theorem just proved, therefore, the angular deflection ϑ produced by the torque T is

$$\vartheta=\left[\frac{dW}{dK}\right]_{K=0}=\left[\frac{l}{2G}\int_0^A 2(q+Kq^1)q^1dA\right]_{K=0}=\frac{l}{G}\int_0^A qq^1dA.$$

Since $\frac{q}{q^1}=\frac{T}{1}$, or $q^1=\frac{q}{T}$, this becomes

$$\vartheta=\frac{l}{GT}\int_0^A q^2dA,$$

which is the required general formula for the torsional deflection of a prismatic shaft.

Applications.—Circular Shaft.—Consider a cross-section perpendicular to the axis of the shaft and choose a pair of rectangular axes OX, OY in the plane of the cross-section and intersecting at the centre O of the circle. Then the component shearing stresses at any point of the circular cross-section with coördinates x, y are

$$q_x = \frac{2Ty}{\pi R^4} \quad , \quad q_y = -\frac{2Tx}{\pi R^4}$$

where R denotes the radius of the shaft. Hence the resultant shear q at this point is

$$q = \sqrt{q^2_x + q^2_y} = \frac{2T}{\pi R^4}\sqrt{x^2+y^2}$$

and consequently

$$\int_0^A q^2 dA = \frac{16T^2}{\pi^2 R^8}\int_{y=0}^{y=R}\int_{x=0}^{x=\sqrt{R^2-y^2}} (x^2+y^2)dxdy = \frac{2T^2}{\pi R^4}.$$

Therefore the total angle of twist for a round shaft is

$$\vartheta = \frac{l}{GT}\int_0^A q^2\, dA = \frac{2lT}{G\pi R^4};$$

or since the polar moment of inertia of a circle is $I = \frac{\pi R^4}{2}$, this may be written

$$\vartheta = \frac{Tl}{GI}.$$

The angle of twist per unit of length, say ϑ_0, is, in this case,

$$\vartheta_0 = \frac{\vartheta}{l} = \frac{T}{GI}.$$

Elliptical Shaft.—For an elliptical cross-section the component stresses at any point x, y, referred to the principal axes of the ellipse as coördinate axes, are

$$q_x = \frac{2Ty}{\pi a b^3} \quad , \quad q_y = -\frac{2Tx}{\pi a^3 b}$$

where a and b denote the semi-axes of the ellipse. Consequently the resultant shear at the point x, y is

$$q = \sqrt{q^2_x + q^2_y} = \frac{2T}{\pi a^3 b^3}\sqrt{a^4y^2 + b^4x^2}.$$

The surface integral becomes in this case

$$\int_0^A q^2 dA = \frac{16T^2}{\pi^2 a^6 b^6} \int_{y=0}^{y=b} \int_{x=0}^{x=\frac{a}{b}\sqrt{b^2-y^2}} (a^4y^2 + b^4x^2)\, dxdy = \frac{T^2(a^2+b^2)}{\pi a^3 b^3}.$$

Therefore the total angle of twist ϑ is

$$\vartheta = \frac{l}{GT} \int_0^A q^2 dA = \frac{lT(a^2+b^2)}{G\pi a^3 b^3},$$

and the angle of twist per unit of length ϑ_0 is

$$\vartheta_0 = \frac{\vartheta}{l} = \frac{T(a^2+b^2)}{G\pi a^3 b^3}.$$

Since the polar moment of inertia of an ellipse is $I = \frac{\pi ab(a^2+b^2)}{4}$, the expression for ϑ_0 may also be written

$$\vartheta_0 = \frac{4TI}{G\pi^2 a^4 b^4} = \frac{4\pi^2 TI}{GA^4}.$$

Triangular Shaft.—For a triangular cross-section, the stress at any point depends on the relative dimensions of the triangle. In the present case consider an equilateral triangle, choose the origin of coördinates at the centre of the inscribed circle and one axis parallel to a side of the triangle, as shown in the figure (Fig. 1). Then if the radius of the inscribed circle is denoted by a, the component stresses at any point x, y are

$$q_x = \frac{5T}{9\sqrt{3}\, a^4}\left(y - \frac{xy}{a}\right), \qquad q_y = \frac{5T}{9\sqrt{3}\, a^4}\left(-x + \frac{y^2-x^2}{2a}\right).$$

Consequently the resultant stress q at this point, is

$$q = \sqrt{q_x^2 + q_y^2} = \frac{5\sqrt{3}\, T}{54a^5}\sqrt{4a^2x^2 + 4a^2y^2 + 2x^2y^2 - 12axy^2 + 4ax^3 + x^4 + y^4}$$

and the surface integral becomes in this case

$$\int_0^A q^2 dA = \frac{25T^2}{486a^{10}} \int_{x=-2a}^{x=a} \int_{y=0}^{y=\frac{x+2a}{\sqrt{3}}} (4a^2x^2 + 4a^2y^2 + 2x^2y^2 - 12axy^2 + 4ax^3 + x^4 + y^4)dxdy = \frac{5T^2}{9\sqrt{3}\, a^4}.$$

Hence the total angle of twist is given by

$$\vartheta = \frac{l}{GT}\int_0^A q^2 dA = \frac{5lT}{9\sqrt{3}Ga^4};$$

and the angle of twist per unit of length becomes

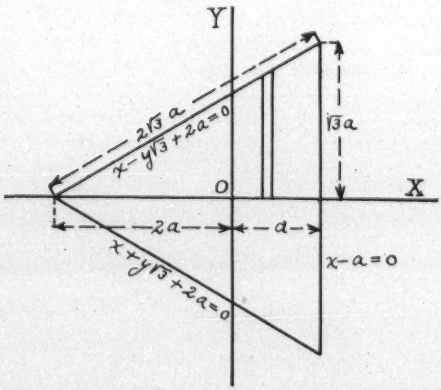
$$\vartheta_0 = \frac{\vartheta}{l} = \frac{5T}{9\sqrt{3}Ga^4}.$$

Since the polar moment of inertia of the triangle with respect to the origin, or centre of gravity of the triangle, is $I = 3\sqrt{3}\,a^4$, this may also be written

$$\vartheta_0 = \frac{5T}{3GI}.$$

Rectangular Shaft.—For a rectangular cross-section with sides of length a and b, choose the origin at the centre of gravity

FIG. 1.



of the rectangle, and the axes parallel to its sides. Then the component stresses at any point x, y are

$$q_x = \frac{9T}{a^3b^3}y(a^2-4x^2),\quad q_y = -\frac{9T}{a^3b^3}x(b^2-4y^2).$$

Consequently the resultant stress q at this point is

$$q = \sqrt{q^2_x + q^2_y} = \frac{9T}{a^3b^3}\sqrt{y^2a^4 - 8a^2x^2y^2 + 16x^4y^2 + b^4x^2 - 8b^2x^2y^2 + 16x^2y^4}$$

and the surface integral becomes

$$\int_0^A q^2 dA = \frac{324T^2}{a^6b^6}\int_{y=0}^{y=\frac{b}{2}}\int_{x=0}^{x=\frac{a}{2}}(y^2a^4 - 8a^2x^2y^2 + 16x^4y^2 + b^4x^2 - 8b^2x^2y^2 + 16x^2y^4)dxdy = \frac{36T^2(a^2+b^2)}{10a^3b^3}.$$

The total angle of twist for a rectangular shaft is therefore

$$\vartheta = \frac{l}{GT}\int_0^A q^2 dA = \frac{3.6lT(a^2+b^2)}{Ga^3b^3},$$

and the angle of twist per unit of length is

$$\vartheta_0 = \frac{\vartheta}{l} = \frac{3.6T(a^2+b^2)}{Ga^3b^3}.$$

Since the polar moment of inertia of a rectangle is

$$I = \frac{ab(a^2+b^2)}{12},$$

this expression may also be written

$$\vartheta_0 = \frac{43.2TI}{Ga^4b^4} = \frac{43.2TI}{GA^4}.$$

Square Shaft.—If the cross-section is square, then $a = b$, and the expression just obtained reduces to

$$\vartheta_0 = \frac{7.2T}{Ga^4}.$$

Radium Content of Secondary Rocks. ARNOLD L. FLETCHER. (*Phil. Mag.*, vi, 23, 279.)—In 82 specimens of secondary rocks the radium was determined by the fusion method. With the exception of the small and relatively unimportant class of calcareous rocks, all the secondary rocks were found to contain very nearly the same quantity of radium, viz., 1.4 x 10^{-12} grammes per gramme. The mean found for the calcerous sediments was 0.8. The coarse detrital sediments contained somewhat higher amounts of radium, on the average, than the fine, classed as argillaceous and schistose.

Siloxide, a Valuable Substitute for Quartz Glass. F. THOMAS. (*Chem. Zeit.*, xxxvi, 25.)—Siloxide is the name given to products prepared by fusing silica with small proportions of refractory acidic oxides, such as zirconia or titania, for the purpose of obtaining materials more resistant to the action of metallic oxides, especially alkalies, than quartz glass, and being less liable to devitrification on heating. Specimens of Z. siloxide or zirconium glass and T. siloxide or titanium glass were examined, and, although these did not exhibit the beautiful silky lustre of quartz glass ("vitreosil"), they possess distinct advantages over the latter with respect to strength, thermal properties (resistance to devitrification), and resistance to the action of alkalies. The zirconium glass with the most strength contained 1 per cent. of zirconia, while that which had the best thermal properties contained 0.5 per cent. The titanium glasses (containing 0.1 to 2 per cent. of titanium) have a somewhat lower resistance to compression than quartz glass, but resist transverse fracture better than the latter and are superior even to zirconium glass as regards their thermal properties.

Colloidal Gold and Platinum. N. PAPPADA. (*Zeit. Chem. Ind. Kolloide*, ix, 270.)—Colloidal gold and platinum solutions, especially the latter, are much more stable than other electro-negative sols. such as Prussian blue, copper ferrocyanide, etc. The sols prepared by Bredig's method of cathodic disintegration are much more stable than those prepared by chemical reduction methods. The activity of electrolytes in causing coagulation of gold and platinum hydrosols follows in general the same order as with other electro-negative sols. Colloidal gold and platinum act as reducing agents, but are much less active than colloidal silver. When colloidal gold is treated with potassium cyanide or hydrocyanic acid, the dark violet color changes to yellow, and the colloidal character is destroyed, for even tri-valent cations such as Al''' or Te''' now fail to produce flocculation. Colloidal gold acts energetically with chlorine, forming gold chloride. With iodine the reaction proceeds much more slowly. Colloidal platinum acts similarly.

Upkeep of Shop-Lighting Systems. C. E. CLEWELL. (*Amer. Mach.*, xxxvi, 13, 501.)—This paper on shop lighting is of considerable interest, and indicates the economy of keeping lights clean and efficient. In brief, attention is drawn to some of the items involved in the maintenance of shop-lighting systems at high continuous efficiency. From the stand-point of economy alone, the expense is justified. When to economy are added the comfort and assistance that a well-regulated system gives to employees, the matter becomes yet more important. The outlay for lighting upkeep is more than compensated by the better illumination, more contented employees, and a more cheerful shop.

SYMPHANY IN STEREOSCOPIC RADIOGRAPHY.[1]

BY

P. H. EIJKMAN, The Hague, Holland.

THREE years ago I published some new methods of stereoscopy and pointed out that from a mathematical point of view Roentgen-ray stereoscopy is a much simpler problem than ordinary stereoscopy with a photographic camera with lenses. With Roentgen rays the object and its projection are on the same side of the centre of projection, whereas with the camera they lie one on either side of this point, and the image is therefore reversed. With the camera, owing to the position of the conjugate foci, the ratio of the distances is fixed, but with the Roentgen rays this is not the case. With the rays, the plate may be at any angle, although I only considered the "normal" case, so as to simplify the construction. I pointed out the mistake of applying the laws of lens stereoscopy to Roentgen stereoscopy, since, in my opinion, the simplest way is to derive ordinary stereoscopy from Roentgen stereoscopy. The so-called "pin-hole camera" is a transition stage between these two; in this the law of conjugate foci does not apply, and there is no principal axis.

I showed that, for the mathematical reconstruction, the two Roentgen plates, or their virtual images, must be superimposed exactly at the same spot and in the same position with regard to the two anticathodes. Further, since the anticathodes must be replaced by the eyes, the distance between the two anticathodes (base of exposure) must be equal to the distance of the optical centres of the two eyes (visual base). In practice this distance may be taken as 65 millimetres.

I stated, thirdly, that the following conditions are requisite for the normal stereoscopic exposure:

1. In the two exposures one plate must be placed exactly in the same place as the other; in other words, the plates must be congruent.

[1] Presented at a meeting of the Section of Photography and Microscopy held Friday, March 8, 1912.

2. The base of exposure—*i.e.*, the distance between the two positions of the anticathode—must be 65 millimetres.

3. The nearest point of the object must be at least 25 centimetres from the anticathode, since at a lesser distance the eyes do not see stereoscopically.

4. The base must be parallel to the photographic plate, and the middle point of the base opposite the middle of the plate. We may call the perpendiculars from the extremities of the base the "principal axes," and their intersections with the plate the "foot-points."

All other cases may be considered as deviations from the normal exposure, and may be easily deduced from that.

I have worked constantly, since the time of making these statements, to develop these methods, the first of which I named Polyphany.

The pictures made both by ordinary light and by X-rays are what we term, in mathematics, central projection, and, in stereoscopics the connection between the two stereoscopic half-images is expressed by the fact that the exposing distance is the same for both, while the centres of the two projections are separated from each other by a definite distance, which we call the "base-length." It will be readily understood that we may make any number of half-images from points which satisfy these requirements. A given half-image is not limited to one definite complementary half-image, but may be combined with any one of these. The question thus arises whether it may not be of advantage in practice to make the stereoscopic exposure from more than two points. A simple experiment will answer this question in the affirmative.

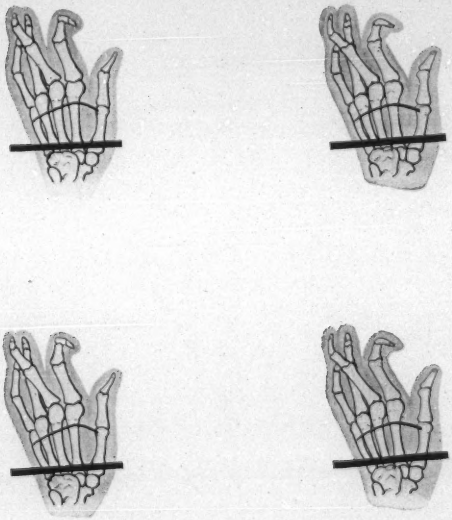
If we hold a cylindrical stick in a horizontal position at a short distance from the eyes, both eyes will receive one and the same image of the stick, and what is hidden from one eye by the stick is also hidden from the other eye.

It is quite different, however, if we hold the stick in a vertical position, for then the left eye sees objects behind the stick hidden from the right eye, and the right eye sees what is hidden from the left. A similar phenomenon may be observed with the Roentgen rays if we place a thick wire parallel to the base before taking a stereoscopic skiagram. There is no representation on either plate of what is situated before or behind the wire, so that it is impos-

sible to decide whether this wire is placed before or behind the object itself. If, however, we place the wire perpendicular to the former direction, we can see quite clearly at what depth the wire is situated.

Fig. 1 shows a skeleton hand, in which the fingers are placed in an unnatural position. Four exposures were made, the respective projection centres making a square of 65 millimetres in a

FIG. 1.



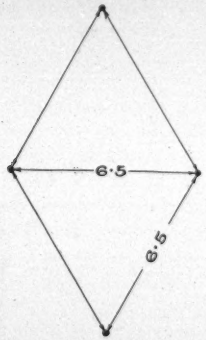
Tetraphany: Plate with a set of four images.

plane parallel to the plate. A metal shaft was placed under the hand in a transverse direction. If we hold the plate so that the fingers point upwards, and examine the two lower images through the stereoscope, we cannot distinguish whether the metal staff is behind or in front of the hand.

Likewise, if we look at the two uppermost pictures, we are still in doubt as to the position of the metal staff. Mathematic-

ally speaking, one has now obtained all the information derivable from these four pictures. Psychically speaking, however, this is not the case. When we turn the plate on its side and examine what is now the upper pair of pictures in the stereoscope, we obtain at once an accurate impression of the position of the metal staff, and on viewing the other pair we get a like result. Other details, such as the shape of the fingers, are also shown much more clearly. This, in my opinion, proves that a series of four such skiagrams, that may be viewed two by two in various ways, has a decided advantage over the usual pair of stereographic negatives. I have named this Tetraphany.

FIG. 2.



Tetraphany in lozenge shape: Position of the centres of projection.

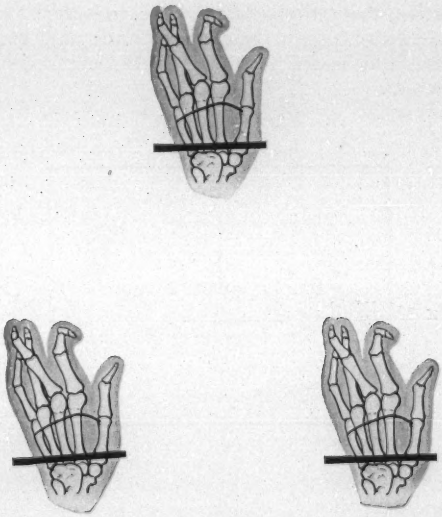
If, instead of a square, we take a lozenge with one diagonal equal to the base, as in Fig. 2, we may obtain five combinations from the four negatives.

The result is almost as good as if we made three such negatives, with the centres of projection at the angles of an equilateral triangle (Triphany), as in Fig. 3. In practice a threefold exposure will probably be sufficient. With the usual oblong shape of photographic plate, it is advisable to place the foot-points of the principal axes in the position shown in Fig. 4.

Instead of placing the three anticathodes at the angles of an equilateral triangle it may in certain cases be advantageous to place them in a straight line.

The X-ray worker knows very well that it makes a difference in what direction he takes stereoscopic pictures of the ribs, and that they are best taken in such a manner that the stereoscopic base is not parallel with the ribs. A triphanic picture of a skull shows that some parts of it are better seen with the base line of the eyes parallel to one base, while other parts are clearer with

FIG. 3.



Triphany: Plate with a set of three images.

the base line of the eyes parallel to the base line of another pair of views.

For the examination of pictures in Triphany it is simplest to have a lens stereoscope with three lenses, the centres of which make an equilateral triangle having sides of 65 millimetres.

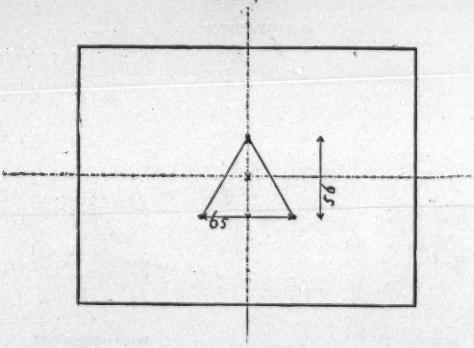
The principle of Polyphany, which I have thus described for Roentgenography, may also be made use of for any other variety of stereoscopy.

The term Symphany relates to the simultaneous and coin-

cident examination of an object by ordinary physical light and X-rays.

In making a stereoscopic picture with X-rays, the body to be radiographed is placed over the plate, with the X-ray tube at some convenient distance. One picture is then taken, say with the tube positioned on the left. A second radiograph is made after changing the plate without disturbing the body, but with the X-ray tube moved to the right. Since, for the mathematical reconstruction, the anticathodes must be replaced by the eyes, the distance between them (base of exposure) must be equal to the distance of the optical centres of the two eyes (visual base) of the operator.

FIG. 4.



Triphany: Position of the three foot-points on the plates.

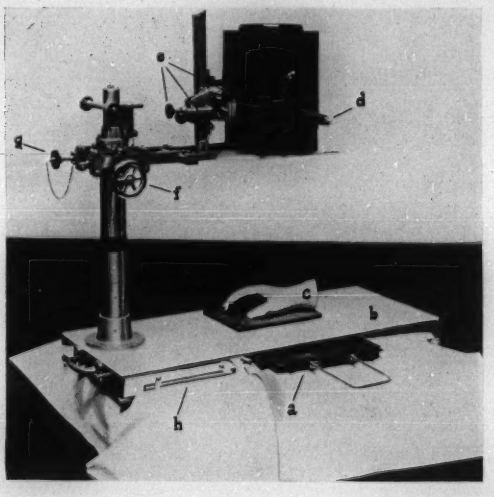
In the mathematical reconstruction by a mirror stereoscope the virtual images must coincide with the original position of the plates. The stereo-image appears on the exact spot where the object lay, exactly the same size and exactly the same shape, so that we may say the stereo-image is congruent with the original object.

It is very readily seen that the operator, having an exact reconstruction, can, by using transparent mirrors instead of ordinary opaque ones, superimpose the solid virtual X-ray image upon the original body, causing the external contour of both solid images to coincide exactly. In the human body one will thus see

the bones through the skin in their exact relative positions. This may serve as a guide to the surgeon during an operation, since he is able to apply his scalpel to the desired spot with mathematical accuracy. This method—*i.e.*, the contemporaneous presence of the object itself together with its Roentgen-ray image—may be termed Symphany.

By removing the object one sees only the Roentgen image

PLATE I.



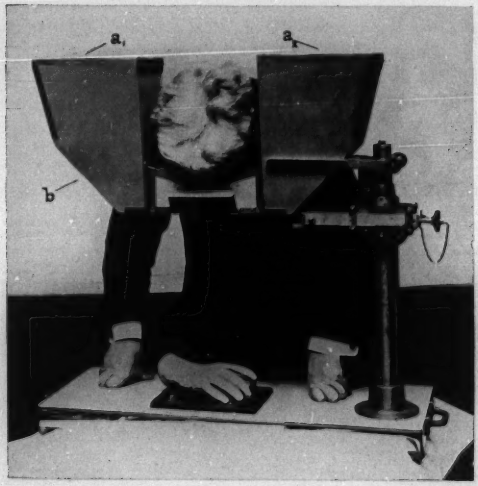
Apparatus arranged for making the two stereoscopic radiographs: *a*. Double plate-holder (plates changed by turning the holder over). *b*. Aluminum sheet. *c*. Body. *d*. Roentgen-ray tube. *e*. Screws for the tube adjustment. *f*. Wheel for the stereoscopic displacement of the Roentgen-ray tube. *g*. Screw for the adjustment of the displacement. *h*. Note-book.

as a nebule of a distinct form. With a piece of white paper every point of this solid image can be touched, indicating in three dimensions exactly where the point lies. A divided rule may be held across this virtual stereo-image in any direction and the exact distance between those two points ascertained. This method, which I call Symphanometry, should prove of use for scientific measurement. In the stereogram is thus possessed not

only a means of giving a general psychical impression, but also a register of the actual mathematical proportions. Perhaps this method could be of value in obstetrics for giving an exact notion of the shape of the pelvis.

In certain cases it might be of advantage to make a permanent record by combining X-rays with the ordinary photographic stereogram. To perform this effectually the centre of projection

PLATE 2.



The symphanor in position: a_1, a_2. Radiographs. b. Mirror set at 45°. The observer looks at a pair of small transparent mirrors.

must coincide exactly with the optical centre of the lens system of the camera, and the displacement must be the same in both cases.

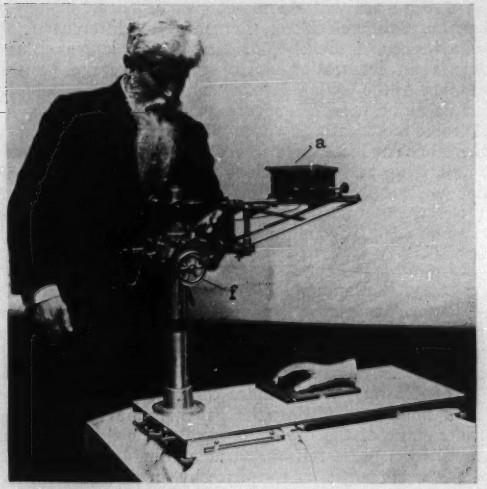
With the same camera one can reduce the X-ray pictures of an object to the same size as the photographic pictures of that object. Then, by using stereoscopic lenses with transparent mirrors at 45 degrees, so that the two sets of pictures can be viewed at the same time, they will be seen to be quite congruent.

On account of the apparent difficulty of a physician troubling himself with so much mathematics, I endeavored to make an instrument that would do this work quite automatically.

In the *Proceedings of the Royal Academy of Sciences of Amsterdam,* March 17, 1909, I gave the full theory. This was reprinted in the *Archives of the Roentgen Ray,* June, 1909.

It was only in the first week in March of this year that I

PLATE 3.



The photographic camera in position: *a.* Photographic camera. *b.* Wheel for stereoscopic adjustment.

received my first working model from the manufactory of Reiniger Gebbert and Schall (Erlangen), and I have to thank Messrs. Kny and Scheerer for giving me an opportunity for testing the apparatus.

I highly appreciated the opportunity of demonstrating it recently, for the first time, before the Academy of Medicine of New York, and now experience the same pleasure in showing it to you.

Boiling-point of Sulphur. (*Engineering*, xciii, No. 2401, 24.)—The exact boiling-point of sulphur has often been determined on account of its importance for thermometry. Messrs. C. W. Waidner and G. K. Burgess (see Bureau of Standards Bulletin, vol. vii, No. 11) have made a new contribution to this research. They boiled sulphur in a Callendar Griffiths apparatus, comprising a glass tube 4.5 cm. in diameter, 45 cm. high, the thermometer coil being mounted within a porcelain tube and enclosed in a radiation shield, 15 cm. long; the resistance thermometer had a length of about 5 cm. The temperature of the sulphur vapor appeared constant within 0.03° C. over a length of 30 cm. of the vapor column. Determinations were then made with thermo-couples of platinum and platinum-rhodium, or platinum-iridium, immersed to different depths, and these were less concordant. Considering that a long resistance thermometer is an integrating device giving average temperatures, the constancy of the boiling-point of sulphur, which is complex in its chemical behavior, possesses several valencies, and is known in several allotropic modifications, appeared doubtful. Other experiments were therefore conducted with a very short resistance thermometer, only 9 mm. long, and with various thermo-couples, finally made of very fine wires only 0.1 mm. in diameter. By this means satisfactory agreement was obtained, and the boiling-point of sulphur appears to be 444.7° C. and to be experimentally constant within at least 0.05° C.

"Pergamyn" Papers. (*French Patent* 435, 589, Oct. 23, 1911.)—Fancy "pergamyn" papers, with greater translucency in some parts than in other parts, are manufactured by preparing a pulp refined in the usual way for "pergamyn" papers and disturbing the moist felt of fibres on the wire of the machine, so as to obtain flaky deformations or more compact agglomerations of the fibres, and finally submitting the paper to heavy pressure at an appropriate stage of the drying process. The desired deformation is produced by a press roll placed at a suitable position above the wire, which is supported at the place by an arrangement fixed underneath. Owing to the irregular distribution of the fibres, only the projecting lumps become compressed under the heavy pressure subsequently applied, so that the paper becomes translucent at these points.

An Alloy for Safety-Valve Seats. (*Brass World*, viii, 4. 120.)—A cobalt-chromium alloy for use as safety-valve seats has been patented by Elwood Haynes, of Kokomo, Ind. It is called "stellite," and can be made of any required degree of hardness, hard enough for use in cutlery, if so desired. It is very non-corrosive, even more so than nickel, and rivals gold and platinum. Its value as a safety-valve seat lies in that it does not wear and never corrodes.

NOTE ON THE RIDEAL-WALKER PHENOL CONTROL.[1]

A Possible Discordant Factor in the Standardization of Disinfectants.

BY

J. T. AINSLIE WALKER, F.R.S.M., F.C.S., and JOHN MORRIS WEISS, B.S., B.A.

WITH the development of chemistry as a quantitative science, used in many and diversified industries, a pressing demand for pure reagents arose. Methods for insuring the purity of chemicals used in quantitative analysis were developed, and to-day this feature has been brought to a state of high perfection. Bacteriology, on the other hand, is in the incipient stage of development along quantitative lines, and most phases are still empirical. One feature which to-day is susceptible of exact quantitative determination is the bactericidal standardization of disinfectants. This is best exemplified by the Rideal-Walker test,[1] which, briefly, consists in comparing the strengths of disinfectants which kill B. typhosus in a definite time under carefully standardized conditions with the strength of pure phenol solution necessary to perform the same work under the same conditions. Various modifications have been suggested from time to time.[2 3 4 5 6 7] All, however, use pure phenol as a standard, and on the purity of this standard depends the accuracy of the test.

All previous workers have used the Koppeschar bromine titration method [8] as the means of measuring the purity of their phenol control. This is admirable, so far as the detection and elimination of water are concerned, but it totally fails to indicate another and far more serious impurity.

Phenol, or pure crystal carbolic acid, is almost entirely manufactured from a distillate oil of coal-tar by an extraction process, with subsequent purification by distillation and crystallization. In these processes it is possible to produce a very pure phenol, but ordinarily this is not done. Phenol from such a source always contains some of the next higher homologues—the cresols—the amount varying with the care given to the manufacturing process. The bromine titration does not indicate the

[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, April 25, 1912.

presence of moderate amounts of cresol in phenol, returning both in terms of the latter, the analytical variations due to this cause being negligible. As cresol has approximately three times the bactericidal efficiency of phenol, the error from this cause, as will be shown later, may be a very considerable one. The purpose of this communication is to present a new method for insuring the purity of phenol used in determinations of the bactericidal efficiency of disinfectants, and to show by experiment that the cause mentioned above probably accounts for many of the discordant results obtained in the past by different investigators. To insure a pure phenol as a basis for work, the material was synthesized from pure benzene by the Wurtz, Kekule and Dusart sulphonate method, and the product fractionally distilled twice to eliminate water and small amounts of by-products formed in the reaction. The crystallized phenol thus obtained had a solidifying point of 40.5° C. Although some authorities place the melting point of pure phenol at figures varying from 40 to 42.5° C., yet it has been conclusively shown by Eger [9] [10] that the highest purity of phenol has a solidifying point of not over 40.9° C. In view of the fact that our solidifying point was taken on a thermometer recently checked by the United States Bureau of Standards, and that the phenol itself boiled within very narrow limits (0.5° C.), we felt justified in considering that our phenol was absolute, and that the figures as to melting point reported by earlier investigators were incorrect, either because of inaccurate thermometers, or from having to deal with too small quantities of material.

Mixtures of this pure phenol were then made with pure cresols, and it was found that with percentages of cresol from 0 to 30 the lowering of the melting point was constant for any particular degree of impurity, regardless of the variation of the proportions of the three isomeric cresols making up this impurity. The solidifying points were taken on at least 50 c.c. material with the thermometer in the liquid. The point is very sharp, as the thermometer shows a constant temperature over a period of from five to ten minutes.

A curve was plotted, using percentages of phenol as ordinates and solidifying points as abscissæ. From this curve it was possible to deduce from a solidifying point of a dried phenol the degree of cresol contamination. Four phenols obtained from various sources in the open market were thus tested. They were

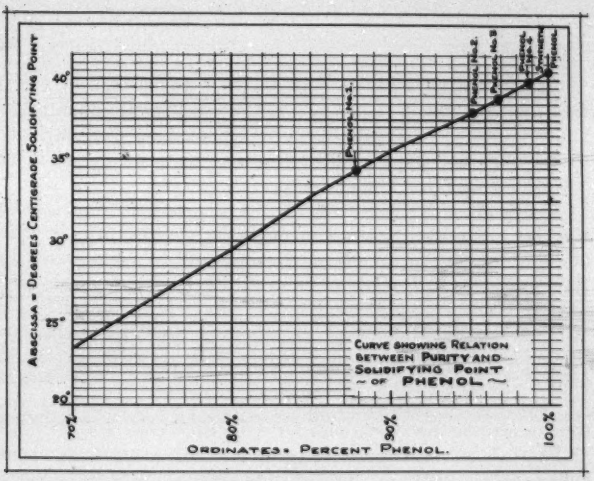
dried before testing by heating about 100 grammes in a distilling bulb until the vapor temperature reached 170° C., experience having shown this to be completely adequate.

The results of these tests showed that the samples varied widely.

TABLE NO. 2.

Material.	Solidifying Point.	Cresols.
Phenol No. 1	34.4° C.	12.0%
Phenol No. 2	38.0°	4.8
Phenol No. 3	38.8°	3.4
Phenol No. 4	39.9°	1.1
Phenol synthetic	40.5°	0

FIG. 1.



These are also shown graphically in the curve accompanying this paper, the points at which the various phenols fell being clearly indicated (see Fig. 1).

Solutions of each of these, of approximately 5 per cent., were then made up in the following manner. About 50 grammes of dry substance were poured into a weighing bottle, stoppered, cooled and weighed to four places of decimals on a sensitive balance. The phenol was melted, then poured out into a litre flask, the weighing bottle being restoppered and reweighed. The

litre flask was filled with water and carefully adjusted to the mark at 15.5° C.

In order to determine if analytical results would indicate the cresol contamination appreciably, samples of these solutions were sent to the Lederle Laboratories of New York City, and there assayed for phenol by the bromine titration method. The results of these analyses are as follows:

TABLE NO. 1.

Material.	Amount actually in solution.	Amount found by analysis.
Solution of phenol No. 1.....	5.34%	5.12%
Solution of phenol No. 2.....	5.14	5.12
Solution of phenol No. 3.....	5.43	5.44
Solution of phenol No. 4.....	5.20	5.22
Solution of phenol synthetic.....	5.41	5.47

It can readily be seen, even in the extreme case of No. 1, that the variation in test is one which would excite no suspicion and could very well, under ordinary circumstances, be attributed to experimental error. These solutions were then used in the bacteriological tests which follow.

A preliminary experiment with the particular strain of *Bacillus typhosus* (obtained through the courtesy of Dr. Park at the New York City Research Laboratories) established the fact that a 1:110 solution of synthetic phenol under Rideal-Walker normal conditions showed life up to 12½ minutes. This dilution was therefore taken in preparing standard solutions of the other four phenols to compare their relative germicidal values.

Five c.c. of each of these dilutions were transferred to a sterile test-tube by sterile pipettes. To each one of these tubes, at intervals of exactly thirty seconds, 5 drops of a 24 hours' culture of *B. typhosus* incubated at 37° C. in Rideal-Walker standard broth were added (the pipette used delivered drops of distilled water weighing approximately 0.05 gramme), and the half-minute interval was accurately continued whilst 30 broth tubes were inoculated with a single loopful of the medicated cultures. Throughout the experiment the temperature of the water bath in which the medication tubes were immersed was maintained at 15° C. Table No. 3 shows the results obtained after the 30 sub-culture tubes were incubated for 48 hours.

To show to what extent these various phenols would affect the coefficient of a disinfectant when used as standard controls, R.-W. determinations were made, taking the same high coefficient disinfectant as the postulant in each case. The results are seen in Tables Nos. 4, 5, 6, 7 and 8, whole multiples of the control dilution being taken in each case when preparing the dilutions of the postulant.

It is interesting, in this connection, to note that the results obtained agree very closely with the calculated theoretical figures, taking the coefficient of cresol as 3.0 (see Table No. 9). It is quite conceivable, had the experiments been conducted with *half* multiples when preparing the various dilutions for test, that the results might have agreed even more closely.

TABLE NO. 3.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Temperature of Water-bath 15° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Phenol No. 1	1 : 110	X						48 hours	37° C.
Phenol No. 2	1 : 110	X	X	X	X			48 hours	37° C.
Phenol No. 3	1 : 110	X	X	X	X			48 hours	37° C.
Phenol No. 4	1 : 110	X	X	X	X	X		48 hours	37° C.
Phenol synthetic	1 : 110	X	X	X	X	X		48 hours	37° C.

TABLE NO. 4.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1650							48 hours	37° C.
Pyxol	1 : 1760	X						48 hours	37° C.
Pyxol	1 : 1870	X	X	X				48 hours	37° C.
Pyxol	1 : 1980	X	X	X	X			48 hours	37° C.
Phenol No. 1	1 : 110	X						48 hours	37° C.

$\therefore$ Rideal-Walker Coefficient $\frac{1760}{110} = 16.0$.

TABLE NO. 5.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710	X						48 hours	37° C.
Pyxol	1 : 1805	X	X	X				48 hours	37° C.
Pyxol	1 : 1900	X	X	X	X			48 hours	37° C.
Pyxol	1 : 1995	X	X	X	X	X		48 hours	37° C.
Phenol No. 2	1 : 95	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1710}{95}$, $\frac{1805}{95}$ = 18.5 (average).

TABLE NO. 6.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710	X						48 hours	37° C.
Pyxol	1 : 1805	X	X					48 hours	37° C.
Pyxol	1 : 1900	X	X	X	X			48 hours	37° C.
Pyxol	1 : 1995	X	X	X	X	X		48 hours	37° C.
Phenol No. 3	1 : 95	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1805}{95}$ = 19.0.

TABLE NO. 7.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710	X						48 hours	37° C.
Pyxol	1 : 1800	X	X					48 hours	37° C.
Pyxol	1 : 1890	X	X	X				48 hours	37° C.
Pyxol	1 : 1980	X	X	X	X			48 hours	37° C.
Phenol No. 4	1 : 90	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1800}{90}$ = 20.0.

TABLE NO. 8.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.

Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710							48 hours	37° C.
Pyxol	1 : 1800	X	X					48 hours	37° C.
Pyxol	1 : 1890	X	X	X				48 hours	37° C.
Pyxol	1 : 1980	X	X	X	X			48 hours	37° C.
Phenol synthetic	1 : 90	X	X					48 hours	37° C.

$\therefore$ Rideal-Walker Coefficient $\frac{1800}{90} = 20.0$.

TABLE NO. 9.

Material.	RIDEAL-WALKER coefficient found.	RIDEAL-WALKER coefficient calculated.
Phenol No. 1	16.0	16.12
Phenol No. 2	18.5	18.25
Phenol No. 3	19.0	18.56
Phenol No. 4	20.0	19.56
Phenol synthetic	20.0	20.00

GENERAL SUMMARY.

1. Phenol crystals are usually contaminated by cresols to such an extent as to make them unreliable for purposes of bactericidal control.

2. This impurity depresses the coefficient of a disinfectant.

3. The bromine titration is insufficient to insure the purity of phenol.

4. The purity must be first determined before the phenol is selected for use.

5. The purity should be established by determination of the solidifying point as outlined in the present paper.

6. The bromine titration should be used as a check on the gravimetric preparation of the stock 5 per cent. solution.

7. The authors present as a recommendation that no phenol showing a solidifying point of less that 40° C. be used for purposes of bactericidal control.

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[6] Fowler, *Royal Army Med. Jour.*, vol. vi, 1907, p. 6.
[7] Sommerville and Walker, *San. Record*, Nov. 29, 1906; May 9, 1907; March 26, 1908.
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[9] *Pharm. Zeit.*, 1903, p. 210.
[10] *Chem. Zeit. Rep.*, 1903, p. 86.

ABSTRACTS OF COMMUNICATED DISCUSSIONS.

My principal comment would be that the proposal to use only phenol having a solidifying point of not less than 40° C. appears superfluous, because of the fact that the United States Pharmacopœia, 8th Revision, official from September 1, 1905, recognized as a legal standard in such matters by Act of Congress of June 30, 1906, already provides that phenol shall have a solidifying point not lower than 40° C. In view of the foregoing, I would deem it the duty of all analysts, in making tests requiring the use of phenol as a standard substance, to adhere, as a matter of course, to a standard at least no lower than that set by the 8th Revision of the United States Pharmacopœia. I have myself tested various samples of phenol supplied in the ordinary course of laboratory routine, and have had no difficulty in obtaining samples complying with the U. S. P. requirement. I have further made inquiries from large manufacturing houses who use but do not manufacture phenol, and who inform me that they have no difficulty in obtaining phenol as above. I am, therefore, forced to think that the samples mentioned by Mr. Walker must have been of materials decidedly below the quality readily obtainable in the market.—DR. G. H. MEEKER, *Dean*, Dept. of Pharmaceutic Chemistry, The Medico-Chirurgical College, Philadelphia, Pa.

The paper suggests a new, or rather an additional, procedure to be followed in testing phenol as to its suitability for use in the determination of the Rideal-Walker coefficient.

All previous workers, it appears, used a chemical test for this purpose, the well-known Koppeschar volumetric method, using bromine. A *chemical* method is obviously unsuited for

the determination of the presence of closely-related substances, as, for example, cresols.

The authors appear to be wise, therefore, in choosing a *physical* property for this purpose. They have chosen a freezing-point method, and it is interesting to note that the freezing point of a solution of cresol in phenol is a linear function of its phenol content and that this proportionality holds as far as 30 per cent. cresol (27 mol. per cent.), and perhaps farther.

It would be interesting to know whether other physical properties, such as specific gravity and refractive index, would also be useful in this connection.

It is very interesting to learn that the bactericidal power of a solution of cresol in phenol is an additive property, depending on relative proportions of the two, so that, knowing the Rideal-Walker coefficient with respect to a phenol which contains cresol, and knowing the proportion of cresol present as determined by the freezing-point method suggested here, the true Rideal-Walker coefficient (with respect to pure phenol) may be readily computed.—ABRAHAM HENWOOD, Department of Chemistry, Drexel Institute, Philadelphia.

Quantitative bacteriological methods have not been, as the authors state, developed to the extent that quantitative chemical methods have been, and one great reason for this is the comparatively few years since bacteriology has received the attention its importance warranted. Another reason why quantitative bacteriological methods have not been developed is the erroneous idea that all variations in experimental conditions influence greatly bacteriological results.

The common idea that the degree of susceptibility and immunity of test animals made accurate quantitative work impossible has largely been disproved. That this idea is erroneous has been well shown in the accuracy with which toxins and antitoxins may be tested. I have personally had a complete series of 250 Gm. guinea pigs live with a dose of 0.003 c.c. of filtered bouillon culture and all of another series die after a dose of 0.0035 c.c. of the same material. A still smaller difference is manifested with tetanus toxin. Dr. Anderson himself told me that he found an appreciable difference in the strength of the government standard of antitoxin because a minute piece of glass had accidentally fallen into the dried serum when he

weighed it. The point I wish to make is that in all probability bacteriological methods are capable of being developed to a greater degree of accuracy than our present chemical methods.

There are several important factors in the determination of the carbolic coefficient besides the purity of phenol which render the results of this determination somewhat variable, and Anderson and McClintic (*Journal of Infectious Diseases,* vol. 8, No. 1) have determined the amount of variation due to several causes. It seems to me that these other factors usually have considerably more influence upon the results than a small amount of cresol in the phenol. I heartily approve of the use of chemically pure phenol being used as a standard, and do not desire to detract anything from the importance of this valuable contribution, but I do want to point out (1) that quantitative bacteriological methods, when perfected, will no doubt prove even more accurate than quantitative chemical methods; (2) that there are other factors in the determination of the Rideal-Walker coefficient that I believe will influence the results obtained to a much greater degree than the contamination of the standard phenol with 1 or 2 per cent. of cresol; (3) that the specifications proposed for the standard phenol should be rigidly observed, because it is one of the factors that will influence the final results.—DR. W. A. PEARSON, Professor of Chemistry, Hahnemann Medical College, Philadelphia.

I appreciate very much the contribution to exact technical method that you make therein, and the importance of requiring the utmost exactitude in all such testing. I am moved to ask you, however, if it be not possible for you to construct a formula for correcting results to a resolution factor that would be the correct one for the 40° melting phenol, even if a phenol of lower melting point were actually used in practice; and would thus permit a modification of your recommendation, embodied in No. 7 of your general summary, to, say, 40° "or corrected thereto."—DR. WILLIAM S. MAGILL, State Bacteriologist, Albany, N. Y.

ANSWER TO DISCUSSION.

Mr. Ainslie Walker, in reply, said:

Although Dr. Pearson has raised a point which deals with a question somewhat outside the scope of this paper, I gladly avail myself of the opportunity to reply. Dr. Pearson, although heartily approving of the use of chemically pure phenol, is of

opinion that there are other factors in the determination of the Rideal-Walker coefficient that influence the results obtained to a much greater degree than contamination of the standard phenol, and that "Anderson and McClintic (*Journal of Infectious Diseases*, vol. 8, No. 1) have determined the amount of variation due to several causes."

I may say that both Dr. Rideal and myself were greatly surprised at Anderson and McClintic's arguments, as set forth in the paper referred to by Dr. Pearson. The only conclusion we could form was that these workers had overlooked certain important contributions to the literature of the subject.

For instance, in a paper published by Dr. Sommerville and myself in *Public Health* (the official organ of the Society of Medical Officers), March, 1906, we called attention to the fact that life in 2½ and 5 minutes, in the phenol control, was the desired result. And Dr. Rideal, in a paper which he read at the 14th International Congress for Hygiene and Demography, at Berlin, in September, 1907, again emphasized the fact. Yet in Anderson and McClintic's paper we read "the great objection to the method, however, and it is almost a vital one, is the latitude allowed in determining the coefficient. This point is strikingly brought out in the following tables." They then set out a table showing life in 2½ minutes only, in the postulant and control, and compare the ratio so obtained with that which they get from another table showing life up to 12½ minutes in the postulant and control!

Far from wishing to shelter behind these two references, I will go further, and say that later experience has proved that strictly comparable results are obtained even up to 7½ minutes.

Dr. Magill's suggestion is an excellent one, but, unfortunately, not practicable. If we were sure that the disturbing influence was due in all cases to the presence of pure cresol, we might suggest the addition of 1 per cent. to the found coefficient for each drop of 1° C. in the solidifying point of the phenol used as control: but, as we find in practice that the disturbing influence may be partly due to the presence of the next higher homologue of cresol, this suggestion cannot be put forward.

Mr. Weiss, in reply, said:

In regard to Dr. G. H. Meeker's comment that a proposal to use phenol having a solidifying point of not less than 40° C.

was superfluous, in view of the fact that the United States Pharmacopœia had already provided such a solidifying point as the lowest limit, I would say that evidently Doctor Meeker has not taken cognizance of a revision sheet of the Pharmacopœia, issued under date of June 1, 1907, in which the requirements for solidifying point of phenol were dropped to 39° C. This limit of the Pharmacopœia would permit the presence of 3 per cent. of cresol, which would lower the Rideal-Walker coefficient from a postulate twenty to at least nineteen. Therefore, although the Pharmacopœia requirements are probably stringent enough so far as phenol for medical purposes is concerned, yet it should not be taken as a standard for *pure* substances to be used in quantitative determinations, either chemical or bacteriological.

Mr. A. Henwood makes the suggestion that possibly specific gravity and refractive index would be useful in detecting the presence of cresols in phenol. I may say that, so far as specific gravity is concerned, this would be of little value, in view of the fact that the three isomeric cresols among themselves have quite varying specific gravities, and that, therefore, two mixtures of quite different degree of cresol contamination might, owing to the relative proportions of the cresols making up that contamination, have identical specific gravitites. So far as refractive index is concerned, I have never done any work on that point, and, therefore, am unable to form an opinion as to the value of such tests. In general, I would say, however, that a refractometer is not an instrument that is readily available in most laboratories, whereas an accurate thermometer should be, and as the solidifying-point method requires only an accurate thermometer to carry out, it is comparatively simple, and within the reach of all.

Artificial Tulle. A. M. AUTY. (*J. Soc. Dyers and Col.*, xxviii, 16.)—A cupro-ammoniacal solution of cellulose, made in the form of a stiff paste, is delivered into a reservoir, the inclined side of which forms a scraper delivering the paste into the hollows of an engraved cylinder revolving against the scraper. The cylinder passes through a coagulating solution, the cellulose (hydrate) being then drawn off as a continuous fabric over a suitable roller. The tulle is then washed, dried, and finished. Many designs, said to be technically impossible in weaving, may be obtained by this process of molding.

NOTES FROM THE BUREAU OF STANDARDS.

STANDARDIZATION OF GOVERNMENT SPECIFICATIONS FOR PORTLAND CEMENT.

In June, 1911, the Secretary of the Department of Commerce and Labor arranged, through the secretaries of the various departments, for a conference of Government engineers for the purpose of unifying the specifications for Portland cement used by the United States Government. At this conference a committee was appointed to consider existing specifications and to recommend a single specification for Portland cement to be used by all departments of the Government.

After an extended series of meetings of this committee, at which careful consideration was given to representative specifications for Portland cement, as well as to all available data on methods of tests, a tentative specification was developed, which was reported to the departmental conference at a general meeting held July 20, 1911.

In view of the desirability of agreement between the specifications in use by the public and those adopted by the Government, the committee was instructed by the conference to confer with representative consumers and manufacturers as well as the special committees of the national engineering societies more directly interested in the subject of cement specifications. As a result the tentative specifications first reported by the departmental committee were modified slightly, until substantial agreement was reached on practically all points except the methods of determining the normal consistency and time of setting, and the following specifications were unanimously adopted by the departmental conference at the meeting held February 13, 1912.

It was recognized that no specification can be considered final, but must be subject to revision from time to time as occasion requires, and provision will be made for such revision by the various Government departments, all of which have adopted the specification as recommended by the conference.

EXECUTIVE ORDER.

It is hereby ordered that all Portland cement that may hereafter be purchased by any department, bureau, office, or independent establishment of the Government, or that may be used

in construction work connected with any of the aforesaid branches of the Government service, shall conform in every respect to the specification for Portland cement adopted by the Departmental Conference at the meeting held at the Bureau of Standards on February 13, 1912, and approved by the heads of the several departments (to be known as the United States Government Specification for Portland Cement): Provided, however, that such specification may be modified from time to time by any similar departmental conference, with the approval of the heads of the several departments.

WM. H. TAFT.

THE WHITE HOUSE,
April 30, 1912.

The National Bureau of Standards, in its general investigation of structural materials, is engaged, among other things, in the determination of the physical properties of concrete. At the suggestion of engineers and others, the Bureau of Standards is investigating the cause of cracking in concrete structures, where the necessity for expansion and contraction joints is questioned. For this purpose reference marks were placed last week on some of the typical old and new concrete work in Wayne County, Mich., also at Greenwich, Conn. Measurements will be taken from time to time during the summer and winter to determine the expansion or contraction in the concrete caused by temperature variations and the changes of volume which take place during the hardening of the concrete. Similar reference marks are being placed on the lock walls of the Panama Canal and various other structures, from which valuable information will be obtained.

The following circulars have just been sent to press by the bureau:

Circular No. 34.—The Relation of the Horsepower to the Kilowatt.

Circular No. 35.—The Melting Points of Chemical Elements.

Circular No. 36.—The Testing and Properties of Electrical Condensers.

Copies of these circulars may be obtained upon application to the Director.

FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, June 5, 1912.)

HALL OF THE INSTITUTE,
PHILADELPHIA, June 5, 1912.

MR. WILFRED LEWIS in the Chair.

The following reports were presented for final action:

No. 2507.—Squier's Multiplex Telephony. Cresson Medal. Adopted.

No. 2517.—Dietz's Multi-speed Shutter. Motion to recommend Scott Award adopted.

First Reading:

No. 2519.—Gibson's Metering Feed-water Heater. Advisory. Adopted.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. GEO. H. MCFADDEN, Eighteenth and Spruce Streets, Philadelphia, Pa.

MR. RAYMOND W. TUNNELL, 15 North Fifth Street, Philadelphia, Pa.

MR. HERMANN DANNENBAUM, care of National Ammonia Company, Frankford, Philadelphia.

MR. WISTAR E. PATTERSON, Electric Storage Battery Company, Nineteenth and Allegheny Avenue, Philadelphia, Pa.

NON-RESIDENT.

MR. J. STEPH. VAN DER LINGEN, Box 59, Kroonstad, O. F. S., Union of S. A.

ASSOCIATE.

MR. JOHN S. NITTROUER, 417 Chelten Avenue, Ashbourne, Pa.

Changes of Address.

MR. J. B. RUMBOUGH, 49 Zillicoa Street, Asheville, N. C.

DR. M. G. LLOYD, 608 Dearborn Street, Room 1350, Chicago, Ill.

MR. HAROLD C. HEILMAN, 1932 Race Street, Philadelphia, Pa.

PROF. HARRIS J. RYAN, Stanford University, California.

MR. EDW. N. DICKERSON, 141 Broadway, New York City.

DR. CHARLES L. REESE, DuPont Building, Wilmington, Del.

NECROLOGY.

Mr. John T. Kille, 1822 Green Street, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

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MORSE, H. W.—Storage Batteries. 1912.
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JORISSEN, W. P., and L. T. REICHER.—J. H. Van't Hoff's Amsterdamer Periods. 1912.
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JONSTORFF, H. J. V.—Das Eisenhüttenwesen. 1912.
LUNGE, G.—The Manufacture of Sulphuric Acid and Alkali. Vol. 3. 1911.
THORPE, E.—A Dictionary of Applied Chemistry. 1912.
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BELLASIS, E. S.—The Influence Exercised by Ships on One Another. 1911.

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PUBLICATIONS RECEIVED.

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College Engineering Notebook for Classes in Technical Schools and Colleges. Designed and arranged by Robert E. Moritz, Professor of Mathematics in the University of Washington. 17 pages of formulæ and tables and blank pages for notes. Quarto. Boston, Ginn & Co., no date.

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Developers and Development. A practical survey of the principal developers and their characteristic points: with reliable formulæ and instructions for their use in negative making. 64 pages, 12mo. New York, Tennant & Ward, no date. Price, 25 cents.

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CURRENT TOPICS.

Setting Properties of Portland Cement. G. HENTSCHEL. (*Tonind. Zeit.*, xxxvi, 557.)—The change in cement from slow to quick setting is due to the presence of alkali carbonates, which, as positive catalysts, have an accelerating influence on the setting process. The addition of only 0.01 per cent. of sodium carbonate in one case reduced the time of setting from about 6½ hours to 20 minutes. On the other hand, the addition of varying amounts of calcium sulphate retards the time of setting, and the cements remain slow setting. The power of catalysts should be determined by comparative experiments. Sodium and potassium carbonates exert an extraordinarily strong positive effect, while calcium sulphate possesses a relatively smaller negative catalytic effect. The positive effect is much more marked when the cements are finely ground. By burning, any alkali present in the raw materials is converted into an alkaline silicate, which has no effect on the setting, but by exposure to the air these silicates, after grinding the clinker, are slowly decomposed into silicic acid and carbonates, especially under the influence of heat. Experiments on a given cement showed that the time of setting was accelerated by heat, with free access of air, but when carbon dioxide was excluded the time of setting was unchanged after heating the cement on a water-bath for an hour. The pronounced effect of carbon dioxide and heat explains why rotary-kiln cement changes much more easily than cement burned in other kilns, and often leaves the mill in a quick-setting condition. Rotary-kiln clinker tends to be hard, and is consequently heated to a considerable extent by grinding—as high as 87° C. sometimes—and on cold days there is less danger of producing a quick-setting cement through the grinding. The change in the time of setting produced by calcium sulphate is independent of the presence or absence of water of crystallization in the calcium sulphate.

A New German Dirigible Airship. ANON. (*Rev. Sci.*, xv, 1470.)—The innumerable accidents to the Zeppelin airships have not discouraged the Germans in their determination to produce larger and larger airships. The Siemens-Schuckert shops are now constructing a dirigible 118 metres long, and of 13.2 m. maximum diameter, with a capacity of 13,000 cubic metres. This envelope is divided into four compartments by three impermeable partitions. Each of the three forward compartments contains an air balloon; the first compartment gives the dirigible's head the appearance of an almost perfect hemisphere, and this is reinforced by a "helmet"

of ten layers of caoutchouced linen. The envelope is of the flexible type. The fourth compartment, kept at the normal atmospheric pressure, is intended to receive the gas which has escaped from the other three through the safety-valves. It is a very elongated cone in shape. The keel, 80 metres long, is a steel frame in which a man can walk around. It carries the reservoirs of water and of gasoline, also the machinery for filling the balloons (2 motors of 24 horsepower) and for working the safety-valves. Its end is the guiding rudder, 5 planes of 4 x 1.4 metres. Three cars are suspended from the keel, which communicate with each other by a mechanical telegraph. The guiding wings are in the middle car. Each of the other two carries a Daimler motor of 125 horsepower, two depressing rudders, two lateral screws, each with two blades, 3 metres in diameter, running at 700 revolutions, and one axial screw with four blades, running at 750 revolutions.

Action of Nitrogen on Magnesium. MATIGNON and LASSIEUR. (*Bull. Soc. Chim.*, ii, 262.)—Magnesium nitride may be obtained in crystalline form by heating the metal in a crucible almost completely closed and placed in a muffle at a temperature high enough for volatilization. The magnesium vapor combines slowly with the nitrogen of the air, forming the crystalline nitride.

Sintering and Fritting. L. PODSZUS. (*Arch. Physik. Chem. d. Glases u. d. keram. Massen.*, 1, 2.)—Even brittle substances soften near their melting point, as is shown by the deformation of thin rods of pure alumina, thoria, zirconia, silica, and magnesia when these are heated below the melting point. Sintering can be greatly influenced by alteration of the surface energy. Tubes of alumina, thoria, silica, magnesia, or zirconia showed much greater sintering when a mercury vapor arc was produced in them during the heating than when the exhausted tubes were heated. The sintering of the oxides mentioned is promoted by the addition of boric acid, which exerts a solvent action.

Loss in the Manufacture of Salt-Glazed Stoneware. E. BERDEL. (*Sprechsaal*, xlv, 161.)—A loss of 33 per cent. was incurred in the manufacture of beer tankards through heavy deposits of undecomposed salt on the ware. These deposits contained iron, but the original salt (though denatured by pyridine to pass duty-free) contained less than 0.1 per cent. of iron oxide. Nor was the fault in the body, as a white porcelain mixing gave a similar loss. The loss was ultimately traced to some sand used in making the gear, which contained iron hydroxide. In the fire the volatilized salt caused iron chloride to drip on the ware below each piece of gear, thereby preventing the chemical action of salt-glazing. A new source of sand obviated the loss.

Action of Pure Distilled Water, with or without Electrolytes, on Metals. M. TRAUBE-MENGARINI and A. SCALA. (*Z. Chem. Ind. Kol.*, x, 113.)—Experiments on the action of water, under different conditions, on the metals iron, zinc, copper, nickel, tin, and lead are described, and in all cases the formation of colloidal solutions of the metals was observed, as shown especially by ultramicroscopic examination.

Deflocculation of Artificial Graphite. E. G. ACHESON. (*Eng. News.*, lxvi, 677.)—Clay is deflocculated by agitation in an aqueous solution of tannin, then sodium chloride is added, which precipitates or flocculates the clay. To obtain deflocculated graphite, artificial graphite is ground till it will pass a sieve with 40,000 meshes per square inch, and then is macerated with a solution of tannin (about 5 per cent. of the weight of the graphite) or with extracts of straw or infusions of tea, etc. Deflocculated graphite is flocculated by the addition of acid. The following substances can be deflocculated: artificial graphite, natural graphite, amorphous silica and alumina, lampblack, and siloxicon (SiC_2O). Organic washes which will produce deflocculation are solutions of tannin, or of organic substances containing tannin solutions of the gum of the peach and cherry tree, extracts from straw or grass or of barn-yard offal. Electrolytes are flocculating agents. Recent microscopic examination shows that deflocculated graphite, as in oil-dag or aqua-dag, is a true colloid. Acheson thinks that the subdivision of the particles stops short only of the molecules.

Chemical Action of Penetrating Radium Rays. A. KAILAN. (*Monats. Chem.*, xxxiii, 71.)—Potassium iodide, both in neutral and acid solution, is decomposed more rapidly than sodium iodide by penetrating radium rays in the absence of light. The rate of decomposition is increased by increasing the concentration of the salt (though in a less degree), and by the addition of small quantities of acid; it also increases with the strength of the radium preparation, though more slowly, as observed in the decomposition of hydrogen peroxide. With neutral, normal potassium iodide solution, the decomposition at 25° C. was somewhat smaller than at 12° C. and 7° C. The decomposition is considered to be principally due to the direct action of the radium rays on the non-dissociated iodide molecule.

Coating for Iron and Steel. ANON. (*Amer. Mach.*, xxxvi, 13, 508.)—A new process of amalgamating a zinc alloy with iron and steel, called "Lohmannizing," has recently been patented by the Brier Hill Steel Company, Youngstown, Ohio. The process is as follows: The base metal is so treated as to produce a perfect fusion between the protective alloy and the base sheet; the alloy penetrates the minute pores and cavities of the sheet, becoming incor-

porated with it. Photo-micrographs of cross-sections of Lohmannized sheets show that there is a gradual shading off from the alloy to the base, indicating that a second alloy is formed between the original alloy and the protected metal. The thin exterior coating of alloy may crack, but, on account of the alloy formed with the sheet, this will have no effect upon the non-corrosive qualities of the Lohmann metal.

Properties of White Metal. ANON. (*Amer. Mach.*, xxxvi, 13, 535.)—Tests made at the Royal Laboratory at Gross-Lichterfelde-West, to determine the effect of repeated melting, heating, and cooling on the chemical composition and mechanical properties of bearing-metal alloys, show that repeated melting does not make substantial changes in the chemical composition of white metal. The percentage of copper in the alloy increases by about 0.2 of 1 per cent. for each melting, but the ratio of tin and antimony remains the same, although the absolute percentage of these metals in the alloys decreases by about 1.4 per cent. after five meltings. Further, it was found that when white metal is heated and then cooled its mechanical strength is increased by rapid cooling and decreased by slow cooling; slowly-cooled metal is about 10 per cent. weaker.

Natural Gas. ANON. (*Amer. Mach.*, xxxvi, 14,547.)—In a bulletin recently published by the Bureau of Mines on "Liquefied Products from Natural Gas," it is pointed out that by fractionating natural gas, either during or after liquefaction, four commercial products can be obtained. These are: (1) The common natural gas of commerce; (2) the semi-liquid product, known as the new "wild" product, which should be used only as a liquefied gas, and should be kept in high-pressure steel containers only; (3) the light liquid product, or light gasoline, used for blending with heavy naphthas; and (4) the heavy liquid product, or ordinary high-grade gasoline. The possibility of handling the second product, the semi-liquid or "wild" product, in the same manner as Pintsch and Blau gases are handled, manifestly opens a new field of comparatively great importance in the natural-gas industry.

Blackening Small Iron Parts. ANON. (*Amer. Mach.*, xxxvi, 16, 631.)—According to *Metalltechnic*, small iron parts are blackened by means of two baths. The first is made by dissolving 10 parts of copperas in 20 parts water, and 15 parts of tin chloride in 30 parts water, and mixing the two; then dilute with about 400 parts water. The second bath is composed of 3¼ pounds of sodium thiosulphate, ⅛ pound hydrochloric acid, and 2 1/5 pounds water. First the sodium thiosulphate is dissolved in hot water, and the hydrochloric acid should not be added till the bath is to be used.

On adding the acid a yellow precipitate of sulphur is formed, which should be removed from the solution by filtering through muslin. The articles are immersed in the first bath for 10 seconds, rinsed with water, and immediately placed in the second bath for three minutes.

A Satisfactory Method of Adding Aluminum to Brass. (*Brass World,* viii, 4, 115.)—The good effect of aluminum in brass castings has been thoroughly demonstrated; it makes the castings sounder, remarkably free from pin-holes, it runs sharper, and the castings come out of the sand cleaner. Usually the aluminum is added to the brass just before pouring. The amount used is so small, however, that it is difficult to alloy it with the brass; it frequently merely floats on the top of the melted metal, and often causes the brass to "flare" and so wastes spelter. The best method of adding it is to first make an alloy of zinc 3 parts, aluminum 1 part, then add this to the brass. Of course, 4 parts of this alloy equals 1 part of aluminum. This alloy is frequently called "aluminized zinc." For ordinary yellow brass work from 2 to 3 ounces of aluminum are used, which is equivalent to 8 to 12 ounces of "aluminized zinc." If more is added, the brass becomes harder and is apt to shrink considerably.

Molten Iron Not Magnetic. (*Brass World,* viii, 4, 126.)—When red hot, iron is not magnetic, but becomes so when it falls to a black heat. Hence, iron can not be removed from molten metals by means of a magnet.

Production of Sound Steel Ingots. SIR ROBERT A. HADFIELD. (*Eng. Mag.,* xliii, 1, 95.)—Numerous devices, both simple and complicated, have been devised for producing sound steel free from all defects, which have given more or less satisfactory results. Generally, however, the heavy cost of the necessary apparatus has barred it from extensive use. The Hadfield process consists in heating the metal in the upper part of an ingot or other mold and maintaining it in a liquid condition by the combustion in contact therewith, or in close proximity thereto, during the cooling and shrinkage of the metal in the lower part of the mold, of solid fuel —*e.g.,* charcoal—by means of a blast of compressed air which is caused to impinge on the fuel while the fuel is directly or indirectly supported by the metal below; also the interposition of a layer of fusible material, such as iron slag, which has no injurious action on the metal, between the metal and the fuel.

The cost of carrying out the method is trifling compared with the large saving gained in reducing loss and waste material. The quality of the product is improved, in that there is less discard and the material is sounder. The system can be applied equally well to

small or large ingots. On a large output the saving is estimated at from $2 to $3 per ton. The ingots obtained are free from blow-holes, piping, and segregation. About 93 per cent. of the ingot may be utilized for commercial purposes. In mild steel the loss is about 8.8 per cent., and in ordinary steel about 7.9 per cent., the rest of the ingot representing salable and serviceable billets.

Zinc Alloys for Galvanizing. L. SÄNGER. (*Zeit. Angew. Chemie*, 2380.)—Alloys containing 96 to 99.5 per cent. of zinc, 0.5 to 1.5 lead, 0.1 to 0.5 iron, 0.01 to 0.1 copper, 0.5 to 2 tin, 0.1 to 0.5 carbon, 0.05 to 0.5 aluminum, are preferable to rolled zinc as anodes, because they cohere even when reduced almost to paper thickness. They are made in the shape of plates and rods, and other forms, from new and old metals.

Propeller Erosion. (*Engineering*, xciii, 33.)—Manganese bronze temporarily solved the problem of preventing corrosion and erosion observed in the earlier type of steel propellers. The introduction of turbines caused the reappearance of erosion often in a serious form; for example, a blade of a wing propeller of the Mauretania eroded to a depth of 2 inches over an area of 3 or 4 square feet in a short time. O. Silberrad's researches have shown that, unlike corrosion, erosion is not selective as between copper and zinc, but that it depends on the structure of the alloy, removing the eutectic and leaving the mixed crystals. As a result of numerous tests an alloy, known as "Turbodium" has been produced. It has a tensile strength of 38 to 40 tons per square inch, a yield point of 18 to 19 tons, with an elongation of 15 per cent. on 2 inches. Under the laboratory standard erosion test, it showed an endurance of 140 hours, as against 24.7 hours for the ordinary high-tension bronze. This result has been confirmed by actual trials lasting from six months to three years on various turbine-driven vessels, none of whose propellers show any signs of erosion up to the present.

Boston Elevated Railway. (*Elect. Rly. Journ.*, xxxviii, 1313.)—In this article there is given a complete account of the system of power generation and distribution of the Boston Elevated Railway. Owing to alterations and additions the whole system has become very complicated, and the original paper should be referred to, in order to arrive at a full comprehension of the subject. The company has a total rated direct-current generating capacity of 51,183 kilowatts, but this will shortly be raised to 64,700 kilowatts by the purchase of power from the Boston Edison Company. This power will be converted from alternate to direct current for the use of the railway. The whole system is in process of being rearranged and simplified.

Electrolytic Oxygen in Cyanide Solutions. T. H. ALDRICH, JR. (*Amer. Inst. Mining Eng., Bull.* lxii, p. 177.)—Experiments made in the laboratory and on the manufacturing scale with 25,000 tons of ore in the factory prove that the extraction of gold and silver is much more complete, especially when sulphides, graphite, grease, and other reducing agents are present, and that much cyanide is saved, when the cyanide is electrolyzed by continuous or alternating currents, with lead electrodes on 110 volt circuits. Eighteen lead plates, ⅛ inch thick, 6 inches square, connected in series, have been in continuous service for over two years. Lead electrodes are more serviceable than those of iron or carbon.

Steel and Wrought-Iron Pipe. ANON. (*Amer. Mach.,* xxxvi, 16, 638.)—Although steel pipe is more extensively used for general purposes around the steam plant than wrought-iron pipe, many engineers are unable to tell by the appearance whether a piece of new pipe is iron or steel, and yet there is a marked distinction. Steel pipe appears smoother, and whatever scale it may bear stands out in small blisters, which reveal a smooth and usually white surface beneath when scraped away. Iron pipe is generally quite rough, often lacks the even symmetry of steel pipe, and its scale lies in heavy flakes. Steel pipe will stand much flattening without fracture, which iron pipe will not. Iron pipe shows a coarse, jagged fracture, on account of the laminated and fibrous structure of the metal, while fractured steel pipe shows a fine crystalline grain.

Action of the Ultra-violet Rays on Sodium Hyposulphite. LOUIS MARMIER. (*Mon. Sci.,* ii, 843, 212.)—The ultra-violet rays from a Westinghouse lamp of about 240 watts were directed on solutions of sodium hyposulphite of different concentrations, placed 6 to 8 cm. from the lamp. The volume varied from 15 c.c. to 200c.c. Under these conditions, in solutions containing less than 6 grammes per litre of sodium hyposulphite, there was formed hydrosulphite after five minutes' exposure, and at the same time sulphur was deposited. Further, under the influence of the ultra-violet rays the hydrosulphite itself is decomposed and only a trace remains after an exposure of 75 minutes. The solution then consists chiefly of sodium sulphite. With concentrations higher than 6 grammes of sodium hyposulphite per litre, no formation of hydrosulphite could be detected, no matter how long the exposure, nor what quantity of liquid was exposed.

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